

Assessments of FY-3A MWTS and MWHS Measurements Using NOAA-18 AMSU-A and MHS

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Outline

- A Brief Description of Chinese Feng-Yun Three (FY-3)
- Comparison between MHS and MWHS
 - ✓ Sensitivity of channel 3 to upper tropospheric water vapor
 - ✓ Sensitivity of channels 4 and 5 to surface pressure
 - ✓ Sensitivity to surface emissivity
- Comparison between AMSU-A and MWTS
 - ✓ Global and scan biases
 - ✓ Scene-temperature dependence of MWTS biases
 - ✓ Root-cause analysis of MWTS biases
- Summary and Future Work



FY-3

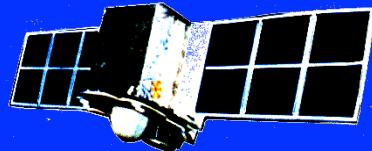
New Era
of Meteorological
Satellite in China



Chinese Meteorological Satellites

Polar-Orbiting

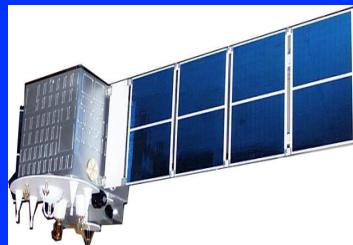
First Generation



FY-1A: 09/07/1988
FY-1B: 09/03/1990
FY-1C: 05/10/1999
FY-1D: 05/15/2002



Second Generation



FY-3A: 05/27/2008
FY-3B: 11/05/2010
8 more: 2012-2020

Geostationary

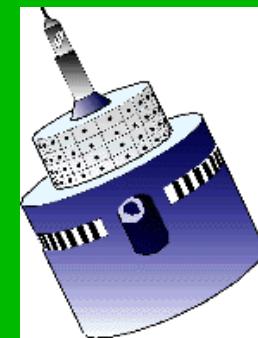
First Generation



FY-2A: 06/10/1997
FY-2B: 06/25/2000
FY-2C: 10/18/2004
FY-2D: 12/08/2006



Second Generation



FY-4: 2013-2020
Total 7

11 Sensors Onboard FY-3

- (1) 可见光和红外扫描辐射计
- (2) 中分辨率光谱成像仪
- (3) 红外分光计
- (4) 微波温度计
- (5) 微波湿度计
- (6) 微波成像仪
- (7) 紫外臭氧垂直探测仪
- (8) 紫外臭氧重量探测仪
- (9) 地球辐射监测仪
- (10) 太阳辐射监测仪
- (11) 空间环境监测仪

11 Sensors Onboard FY-3

- (1) Visible and Infrared Radiometer (**VIRR**)
- (2) Medium Resolution Imager (**MERSI**)
- (3) Infrared Atmospheric Sounder (**IRAS**)
- (4) Microwave Temperature Sounder (**MWTS**)
- (5) Microwave Humidity Sounder (**MWHS**)
- (6) Microwave Radiation Imager (**MWRI**)
- (7) Solar Backscatter Ultraviolet Sounder (**SBUS**)
- (8) Total Ozone Mapping Unit (**TOU**)
- (9) Earth Radiation Measurer (**ERM**)
- (10) Solar Irradiation Monitor (**SIM**)
- (11) Space Environment Monitor (**SEM**)

11 Sensors Onboard FY-3

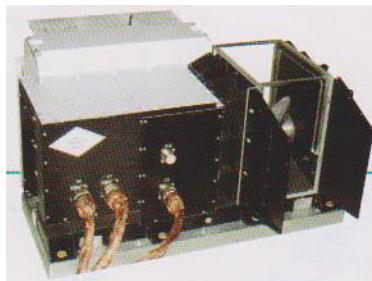
VIRR



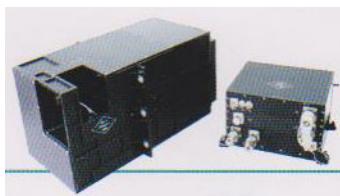
MERSI



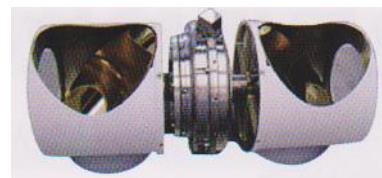
IRAS



SBUS



MWHS



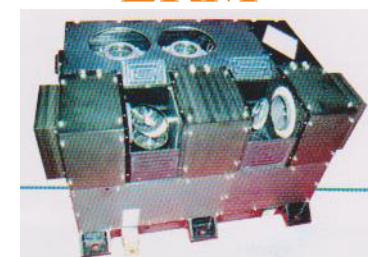
MWRI



TOU



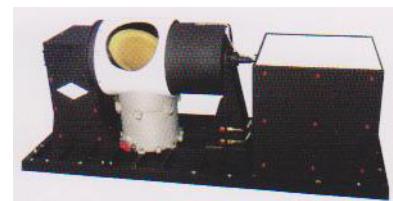
ERM



SIM



MWTS



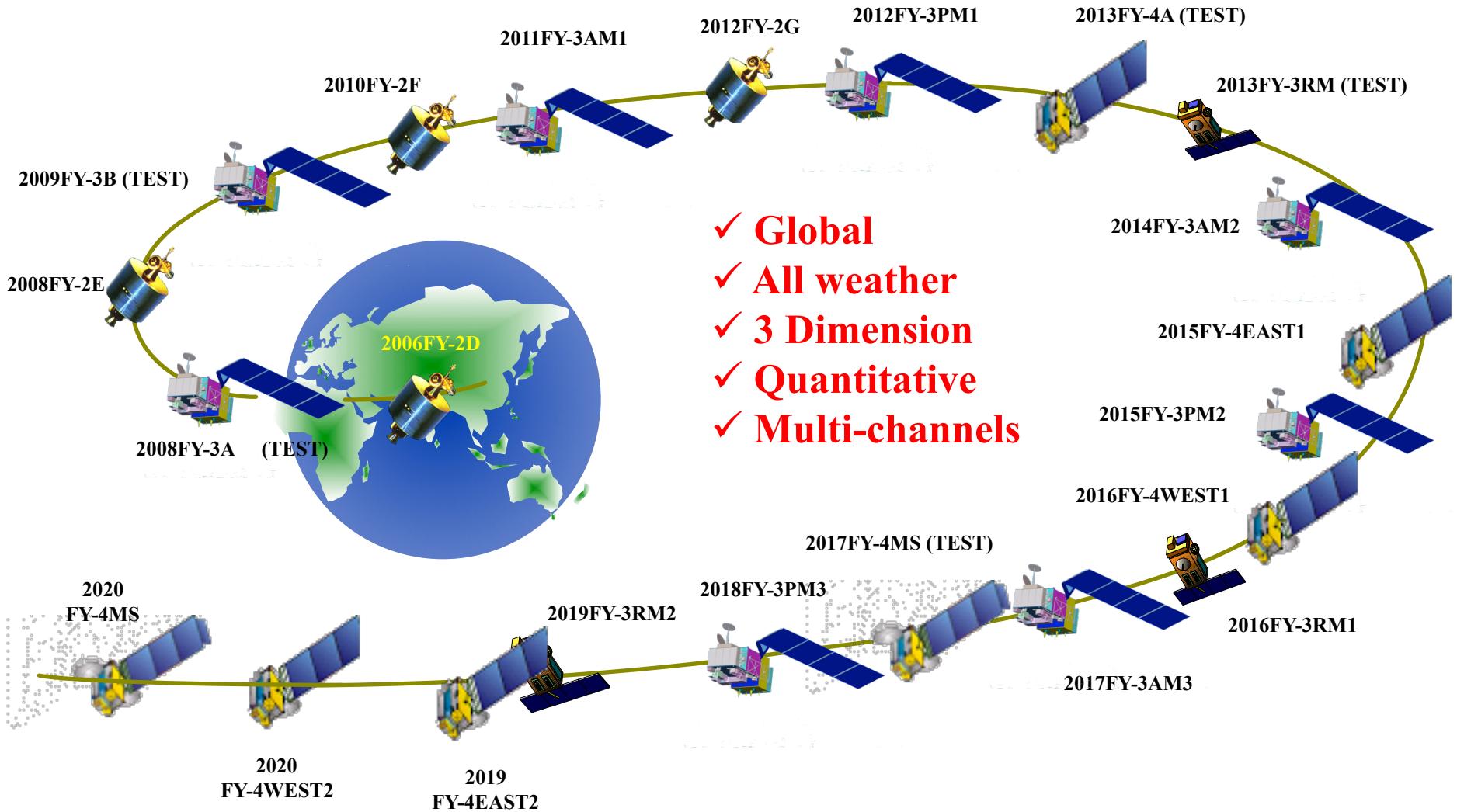
SEM



Instrument Parameters

Instrument	Channel	Wavelength	FOVs	Resolution at Nadir	Purpose
VIRR	10	0.43 – 12.5 μ m	2048	1.1 km	Cloud, aerosol, TPW, vegetation, surface characteristics, surface T ,ice, snow etc.
MERSI	20	0.41 – 12.5 μ m	2048/8192	1.1km/250m	Ocean color, aerosol, TPW, cloud, vegetation, surface characteristics, surface T ,ice, snow etc.
MWRI	12	10.65 – 150 GHz	240	15-70km	Rainrate, LWC, TPW, soil moisture, sea ice, SST, ice, snow, etc.
IRAS	26	0.69 – 15.5 μ m	56	17km	T, q, total O ₃
MWTS	4	50 – 57 GHz	15	50-75km	T
MWHS	5	150 – 183 GHz	98	15km	q, surface characteristics
TOU	6	308 – 361 nm	31	50km	Total O ₃
SBUS	12	250 – 340 nm	240	200km	O ₃ profile
SIM	1	0.2~50 μ m			Solar irradiance
ERM	4	0.2~3.8 μ m 0.2~50 μ m	150	2°×2°	Earth's total radiation, Earth radiance

FY-3 Strategic Plan (2006-2020)



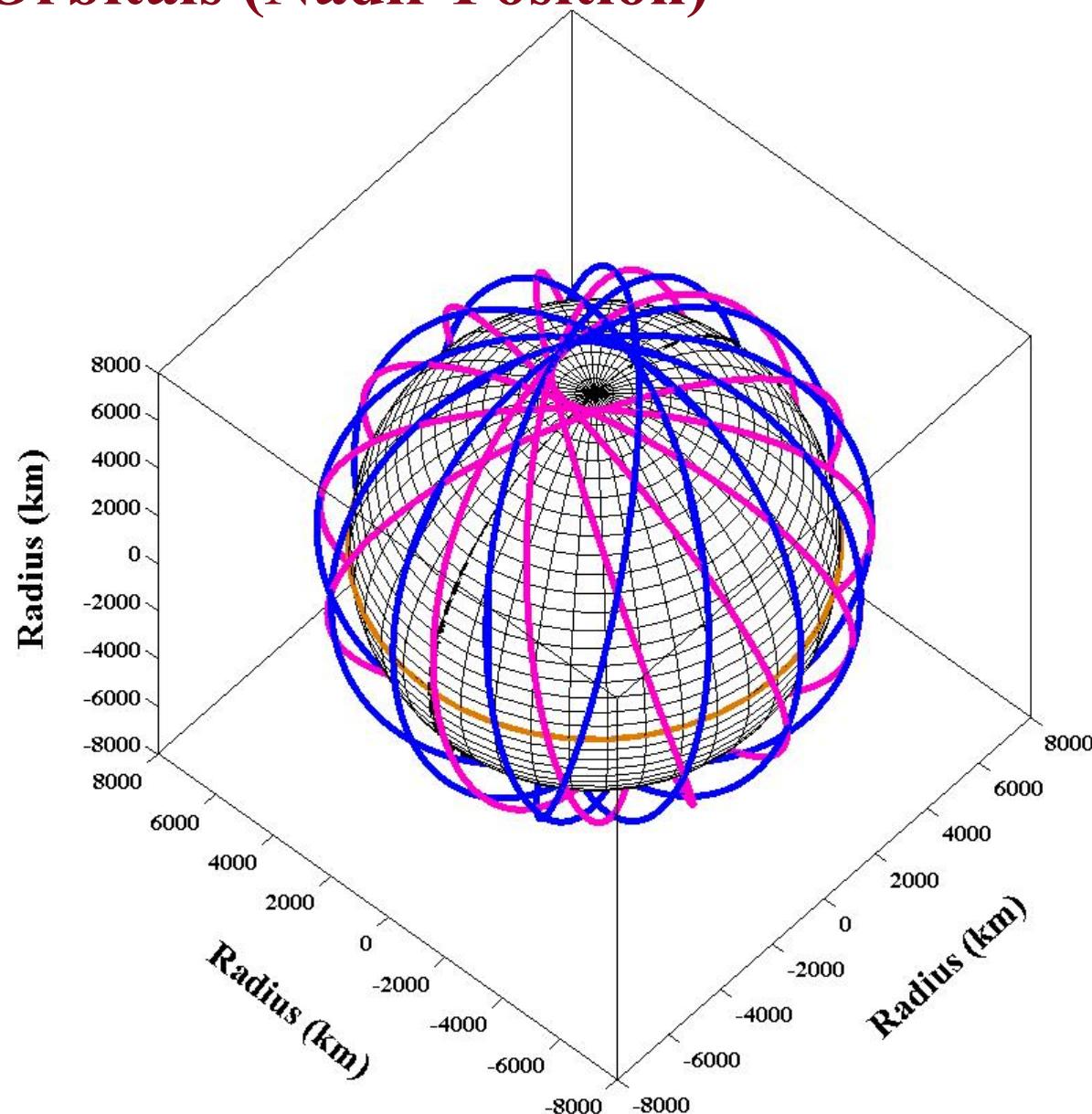
Part II: Comparison between MHS and MWHS



Part III: Comparison between AMSU-A and MWTS



12-hour Orbitals (Nadir Position)



FY-3A
NOAA-18

Accuracy, Precision & Stability

- Requirements for AMSU-A and MHS

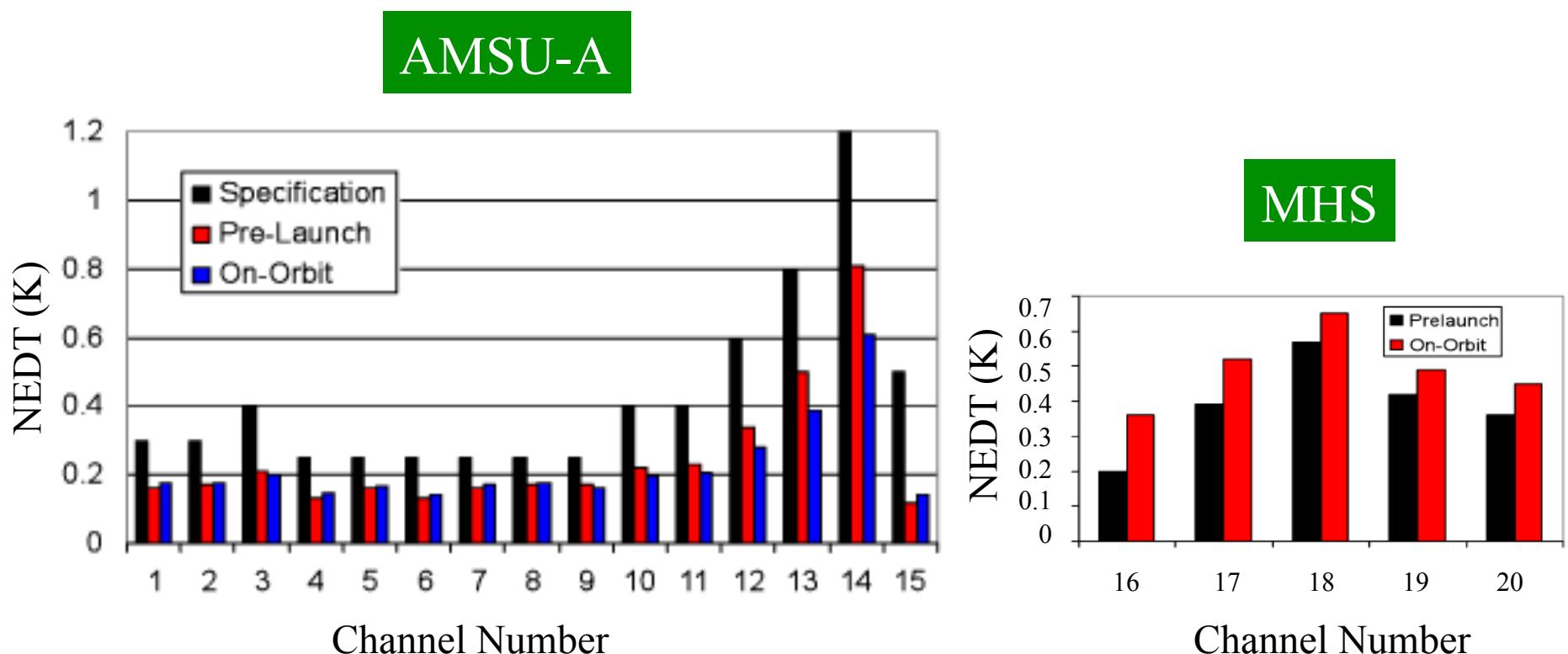
- ✓ Accuracy: 1.0 K
- ✓ Precision (NEDT): 0.25 – 1.2K
- ✓ Stability: None

- Requirements for future system:

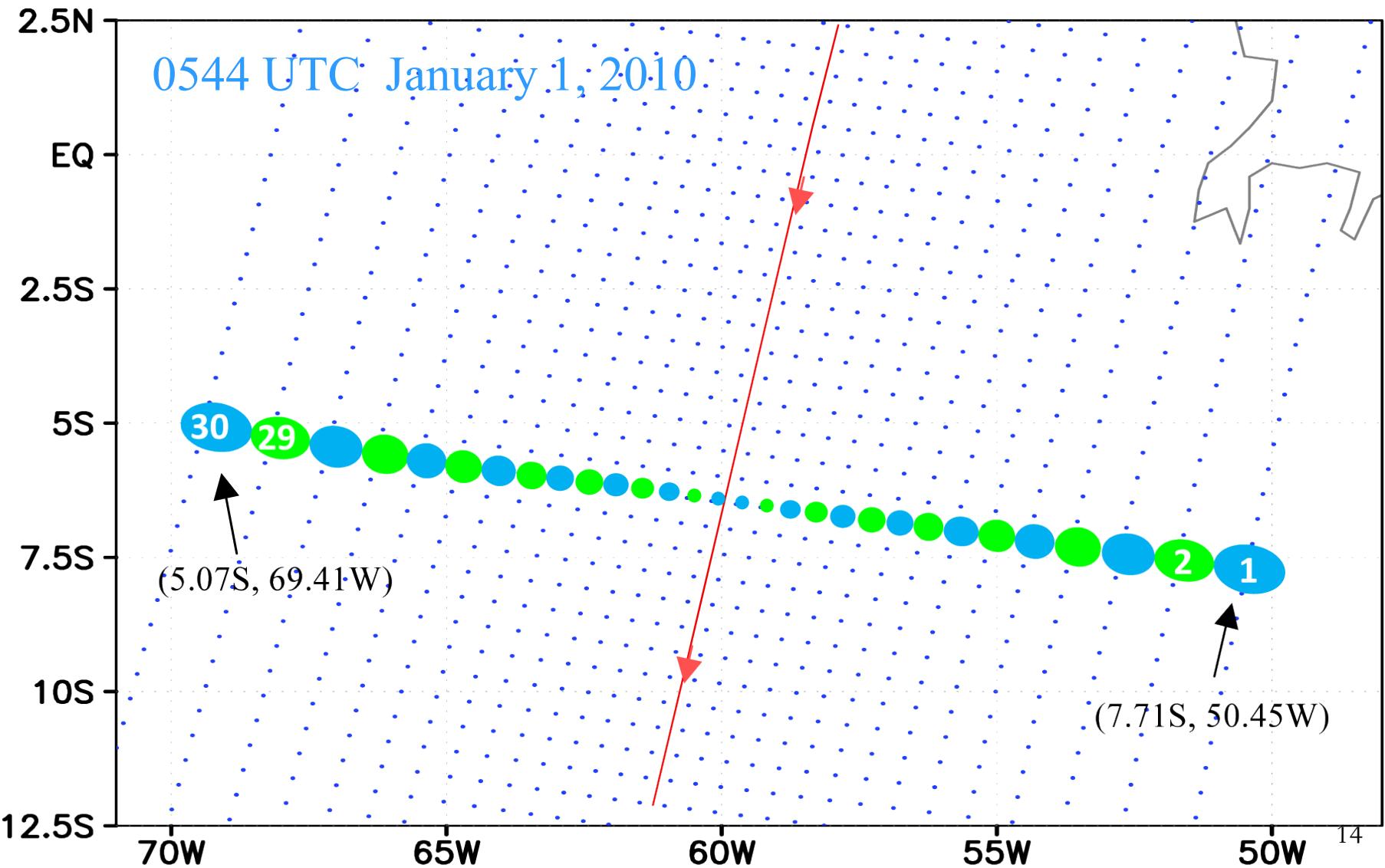
- ✓ Accuracy: 0.5 K
- ✓ Precision (NEDT): <0.1K
- ✓ Stability: 0.04K

Calibration accuracy is normally derived from prelaunch thermal vacuum data, but is difficult to be quantified after a satellite is launched.

Precision of AMSU-A and MHS



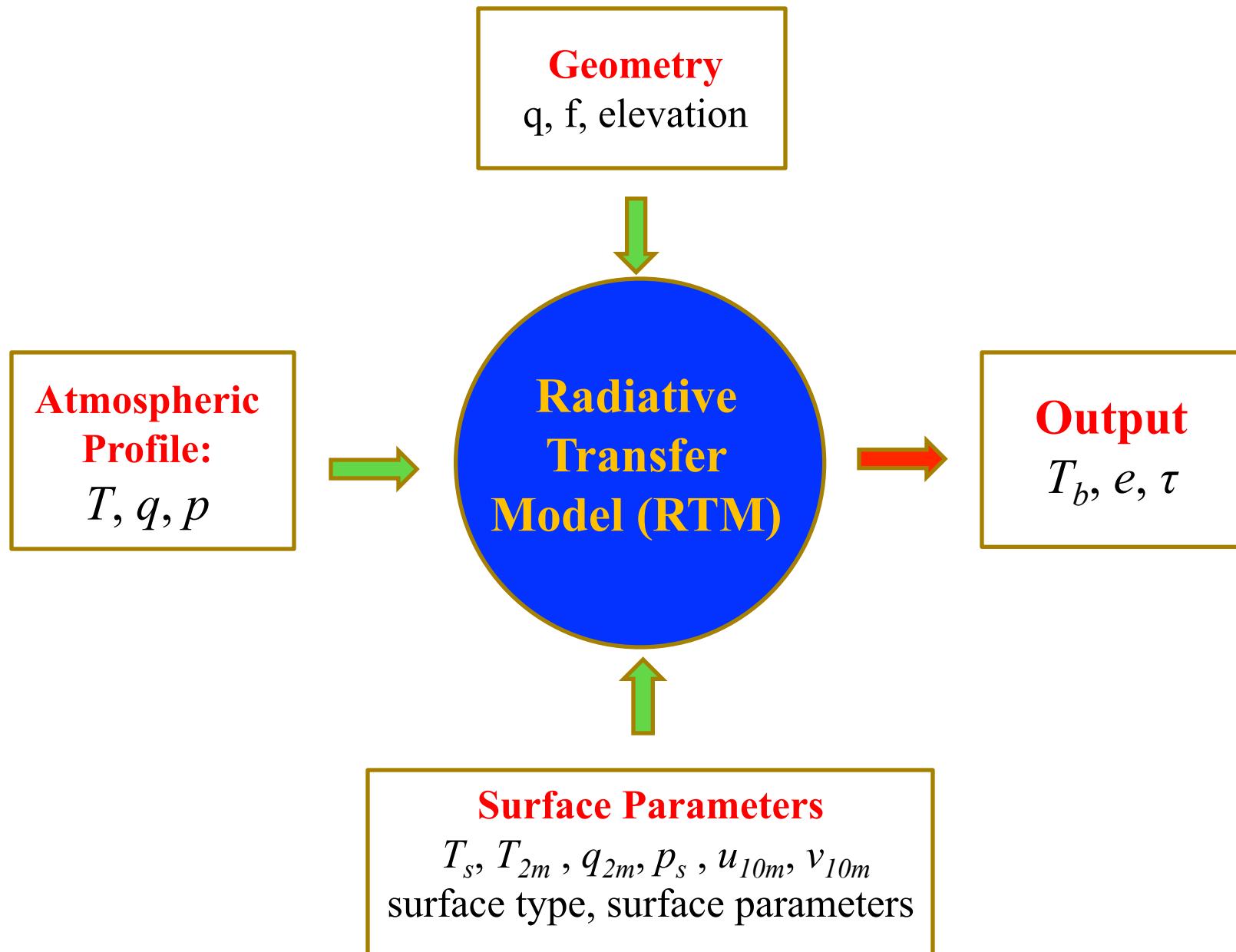
FOVs of AMSU-A from a NOAA-18 Descending Node



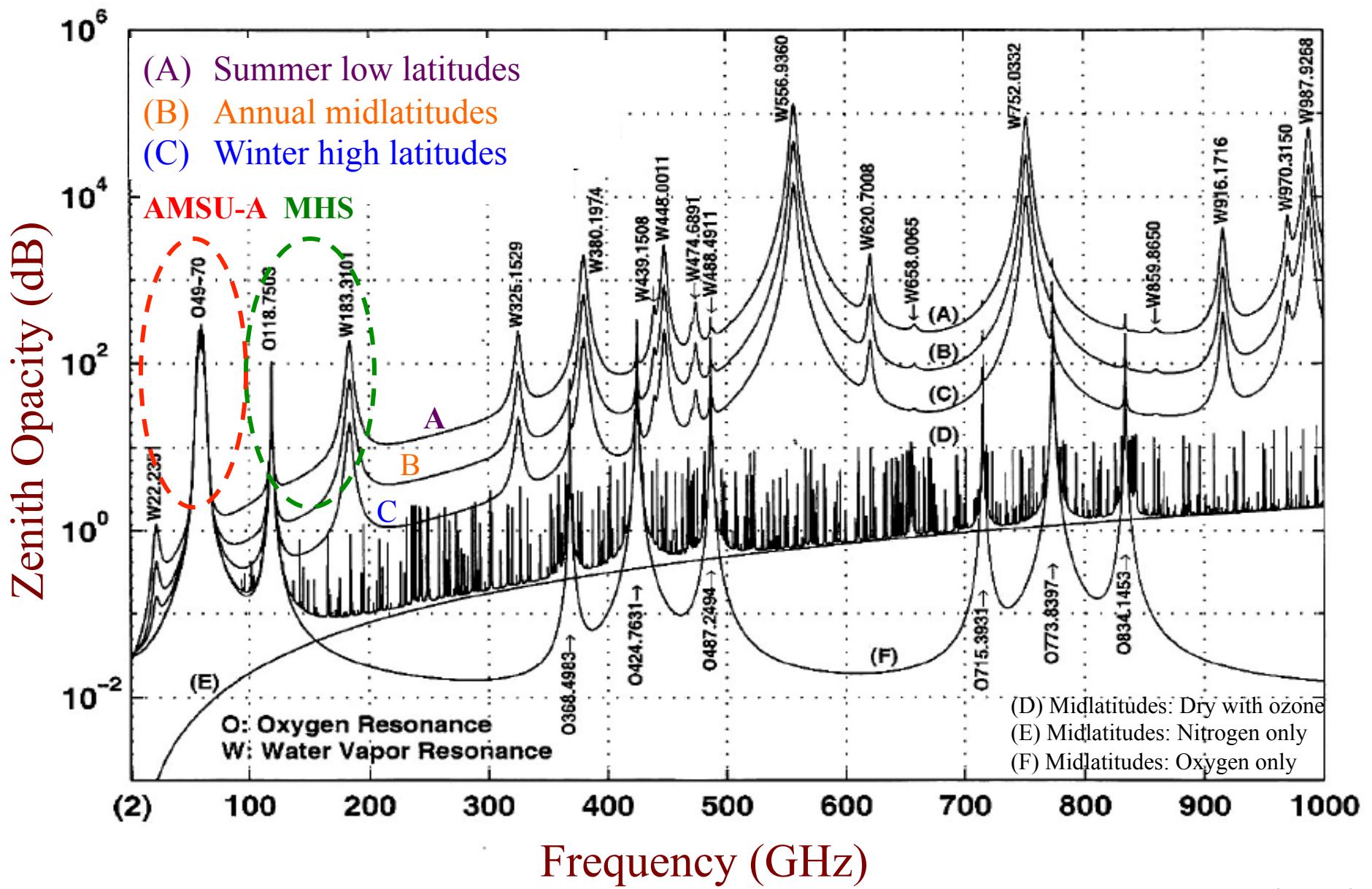
Brightness Temperature Simulation

- 1) Collocate the GFS data with satellite observations
- 2) Interpolate GFS temperature profiles to the standard pressure levels consistent with RTM
- 3) Calculate brightness temperatures at each AMSU-A channels (B)
- 4) Obtain differences between observed and calculated brightness temperatures (O-B)

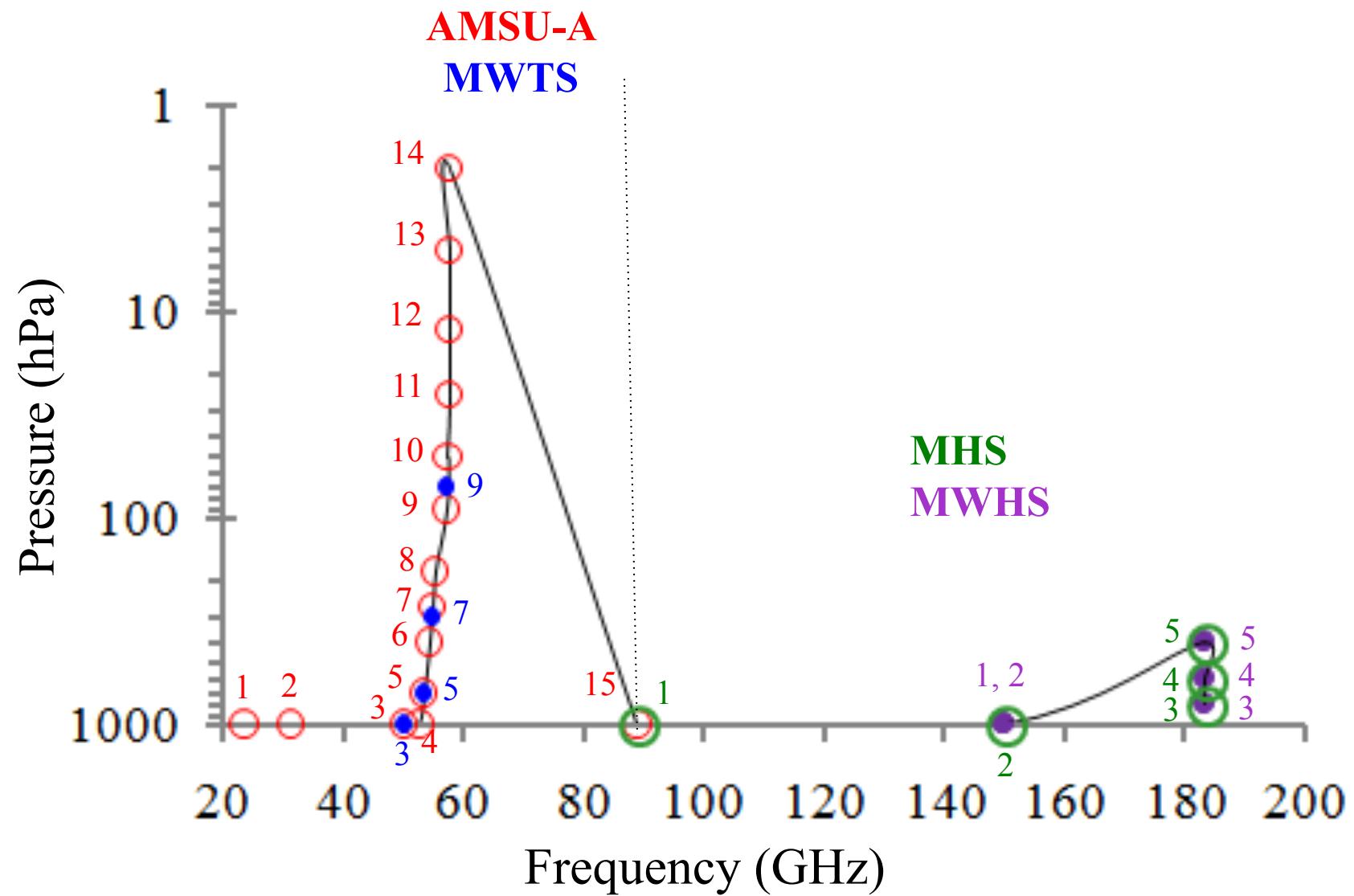
**Statistical characteristics of O-B are compared
between NOAA-18 and FY-3A!**



Physical Basis



Frequency Versus Peak Weighting Function Height



Part II

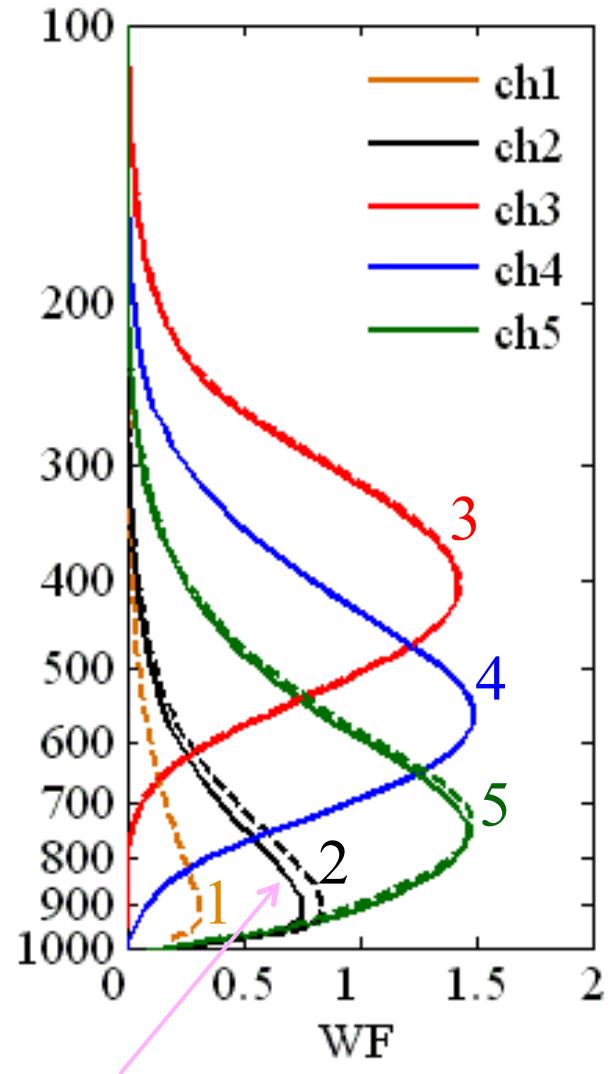
Comparison between MHS and MWHS

- ✓ Sensitivity of channel 3 to upper tropospheric water vapor
- ✓ Sensitivity of channels 4 and 5 to surface pressure
- ✓ Sensitivity to surface emissivity

Comparison of Instrument Parameters between MHS and MWHS

Channel number		Frequency (GHz)		Bandwidth (MHz)		NEΔT (K)	
MHS	MWHS	MHS	MWHS	MHS	MWHS	MHS	MWHS
1	1	89(V)	150(V)	1000×2		0.84	0.90
2	2		150(H)	1000×2		0.84	0.90
3	3		183.31±1(V)	500×2		0.60	1.10
4	4		183.31±3(V)	1000×2		0.70	0.90
5	5		183.31±7(V)	2000×2		1.06	0.90

Channel number		Nadir Res. (km)		WF (hPa)		Swath width (km)	
MHS	MWHS	MHS	MWHS	MHS	MWHS	MHS	MWHS
surface	surface	15	15	surface	surface	2250	2700
surface	surface	15	15	surface	surface	2250	2700
400	400	15	15	400	400	2250	2700
600	600	15	15	600	600	2250	2700
800	800	15	15	800	800	2250	2700



Channels 1 and 2
(FY-3A MWHS)

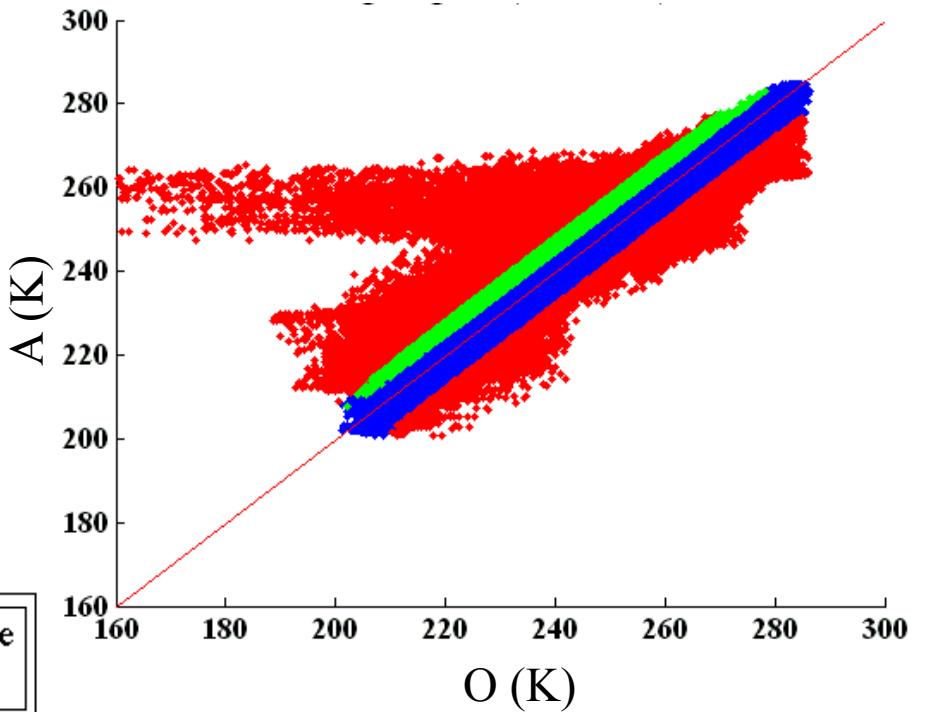
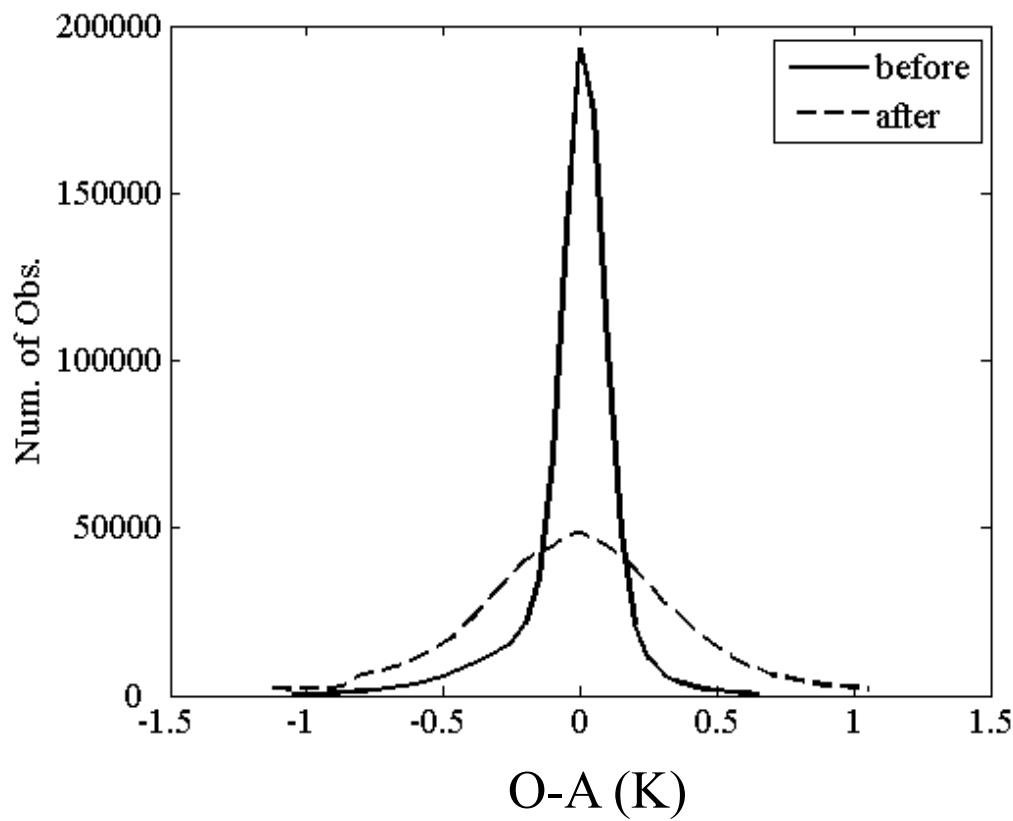
Weighting Functions

FY-3A MWHS: solid line

NOAA-18 MHS: dashed

Channels 3-5 are nearly identical.

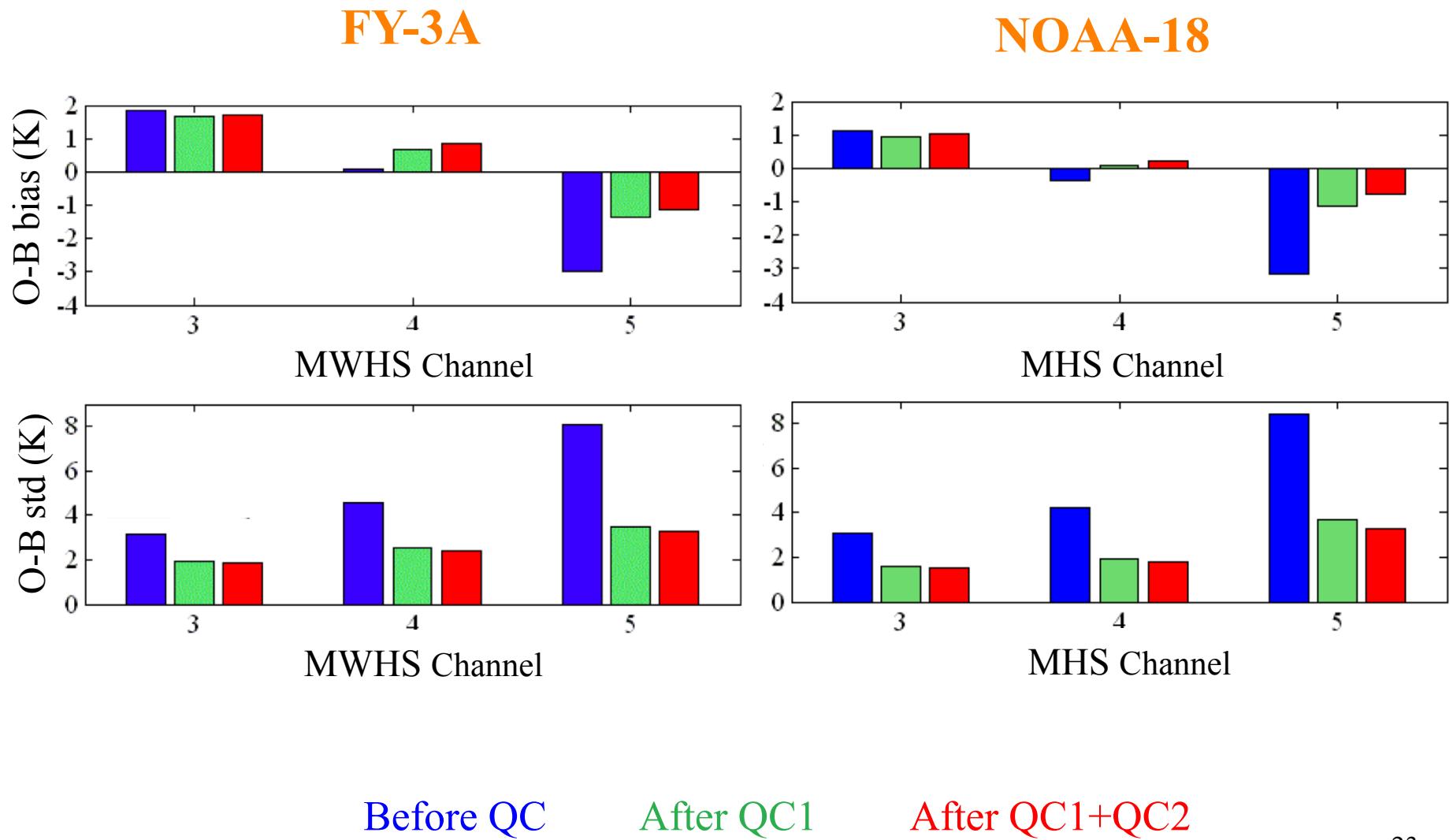
Quality Control



O: FY-3A MWHS Radiances

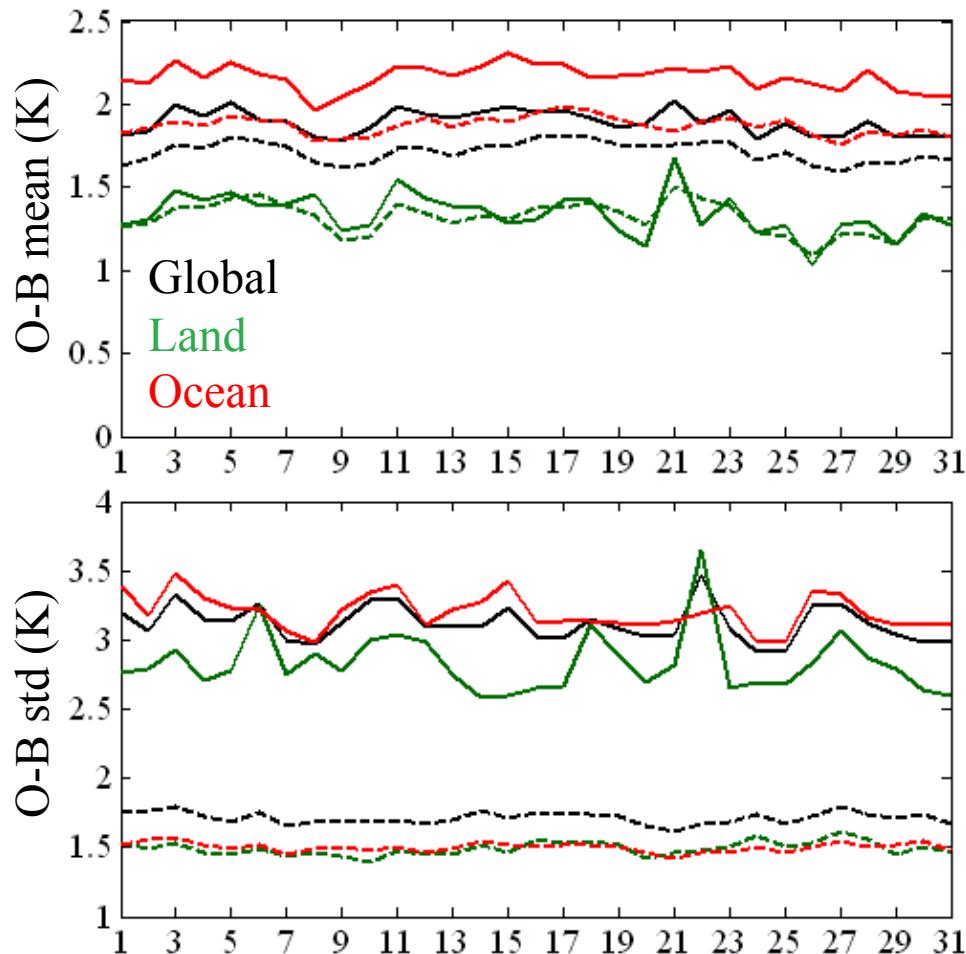
B: RTTOV simulations from
NCEP 6-h forecasts

Biases & Standard Deviations



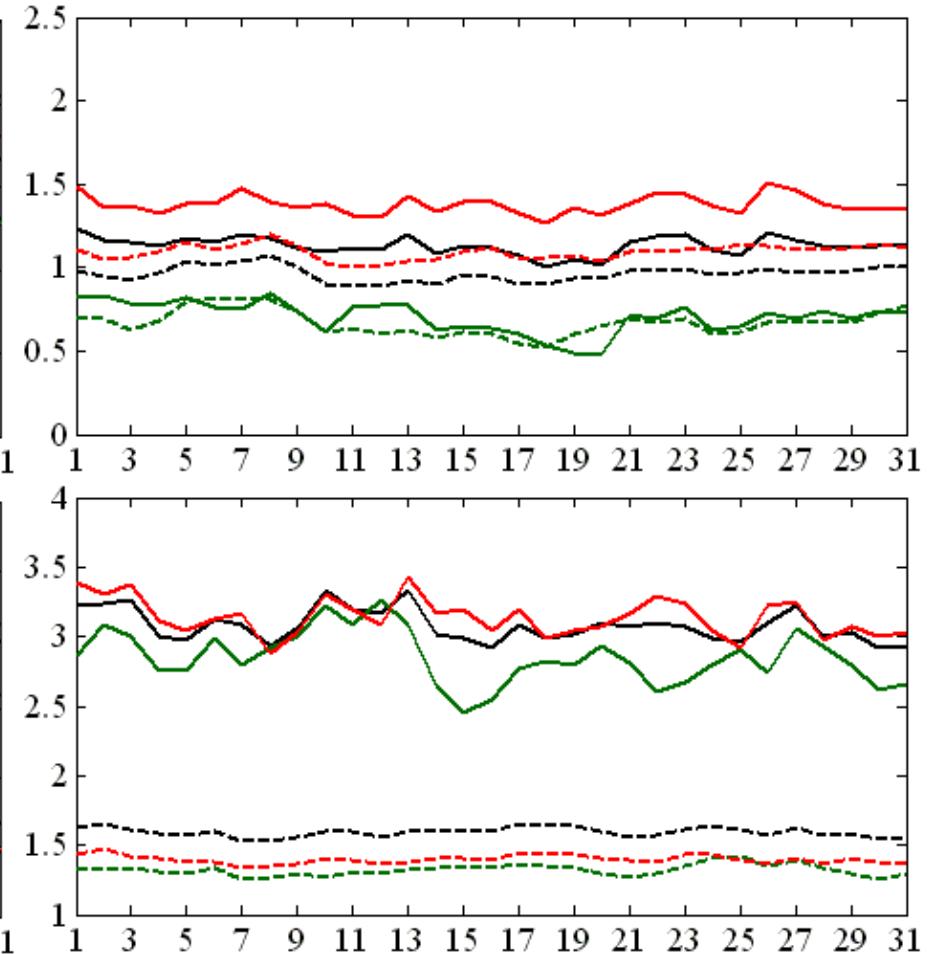
Channel 3

FY-3A



January 2010 (day)

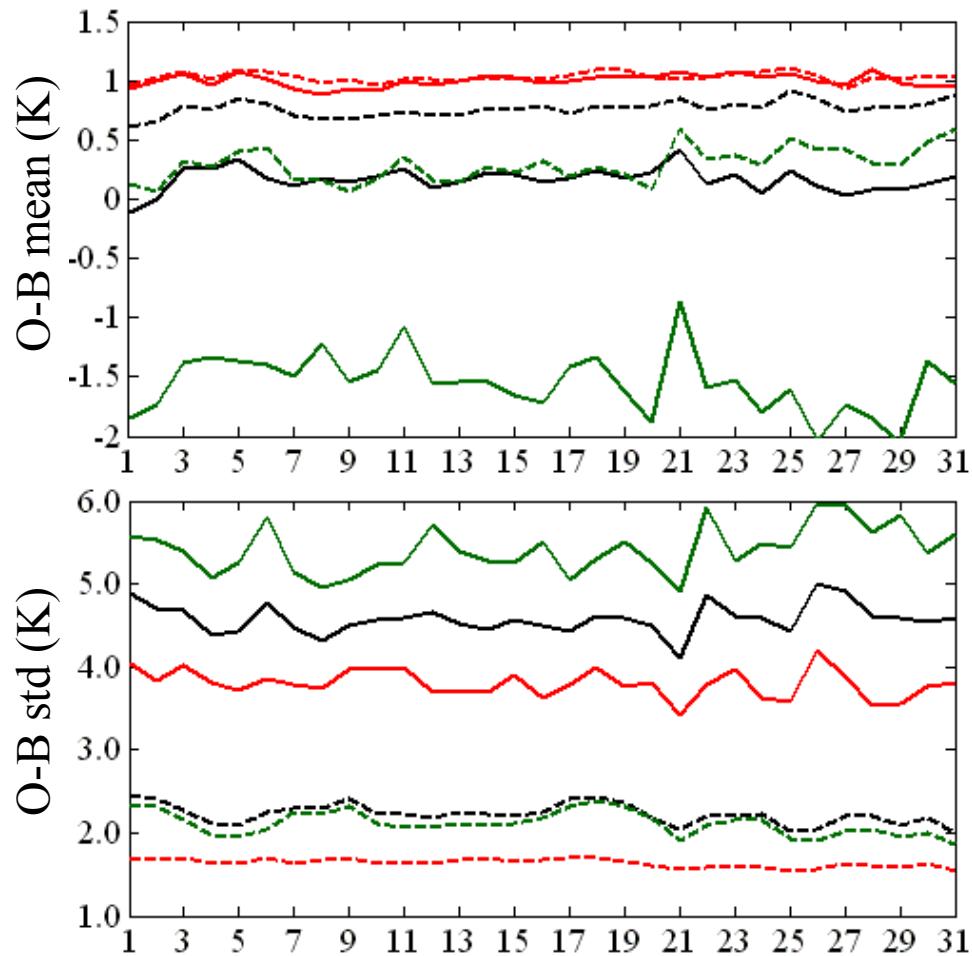
NOAA-18



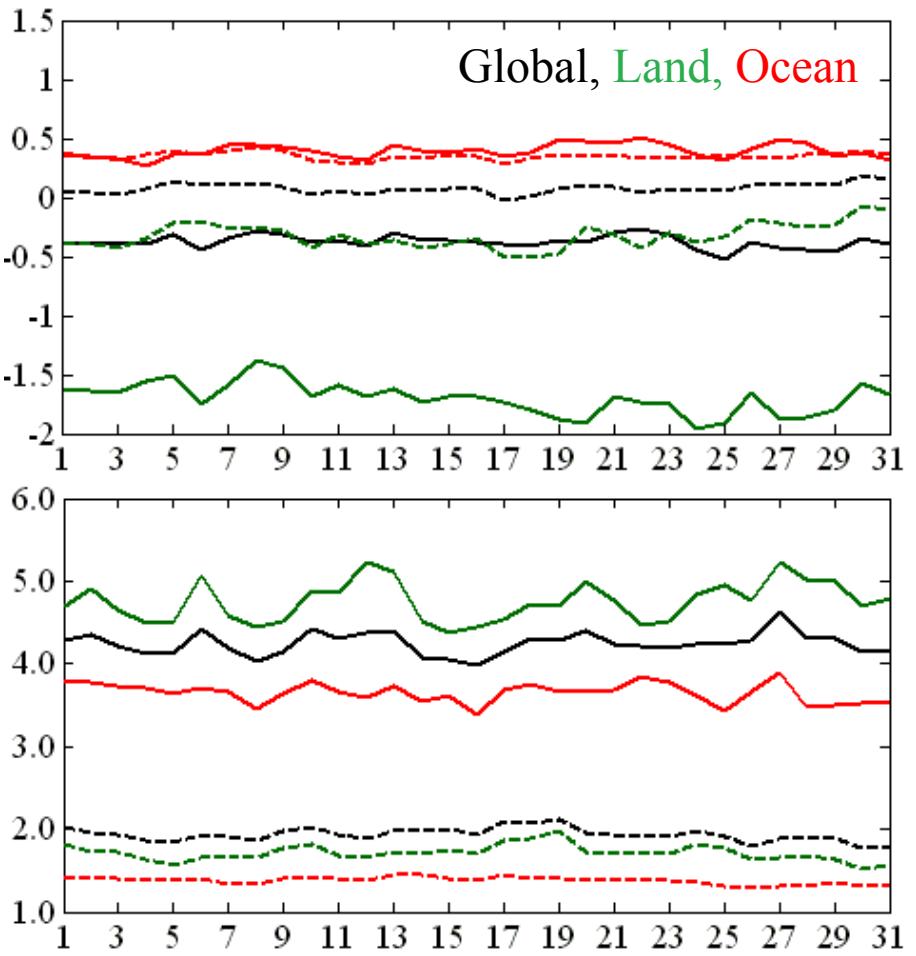
January 2010 (day)

Channel 4

FY-3A



NOAA-18



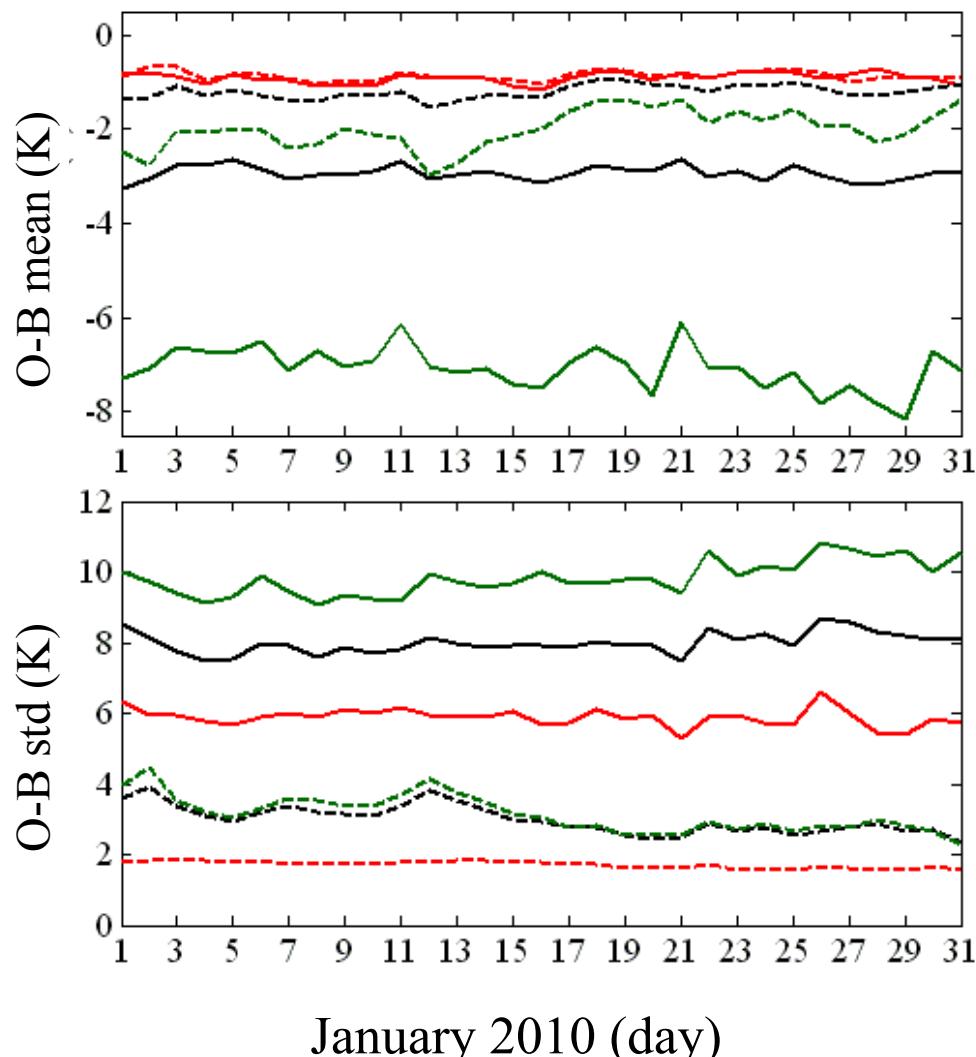
January 2010 (day)

January 2010 (day)

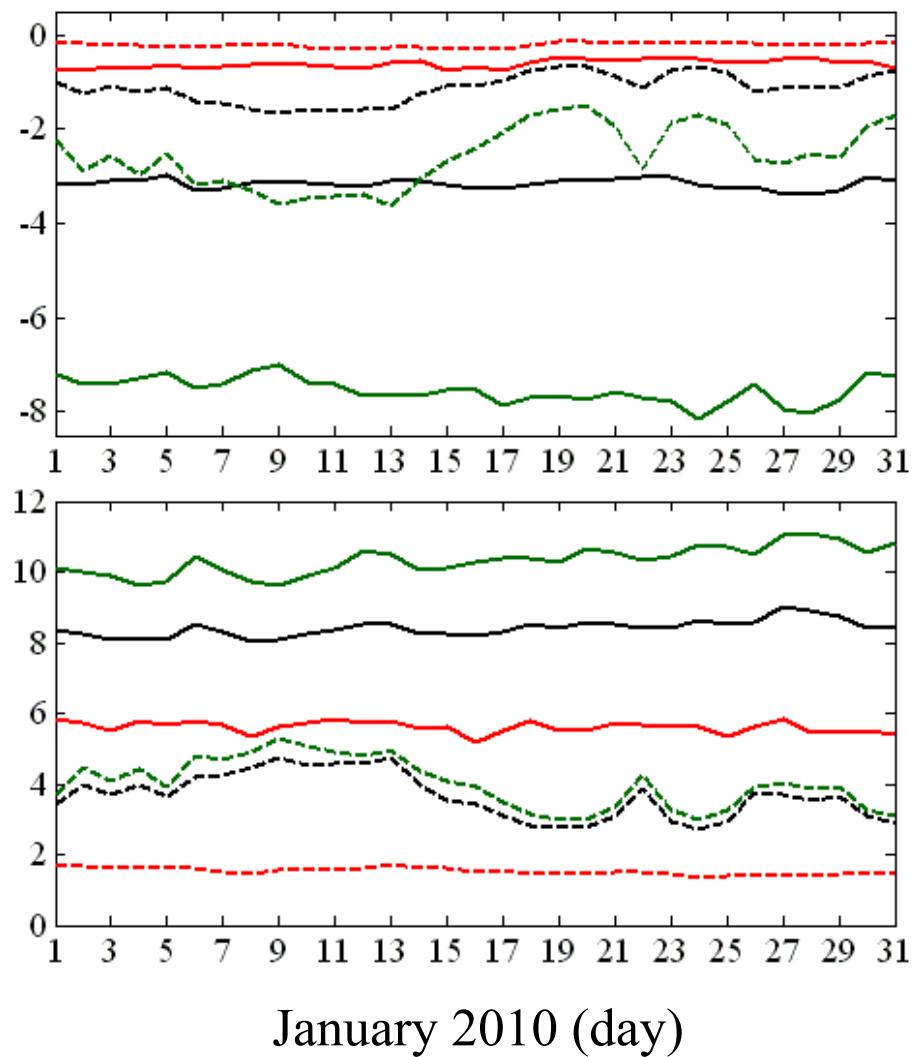
25

Channel 5

FY-3A



NOAA-18



January 2010 (day)

Global, Land, Ocean

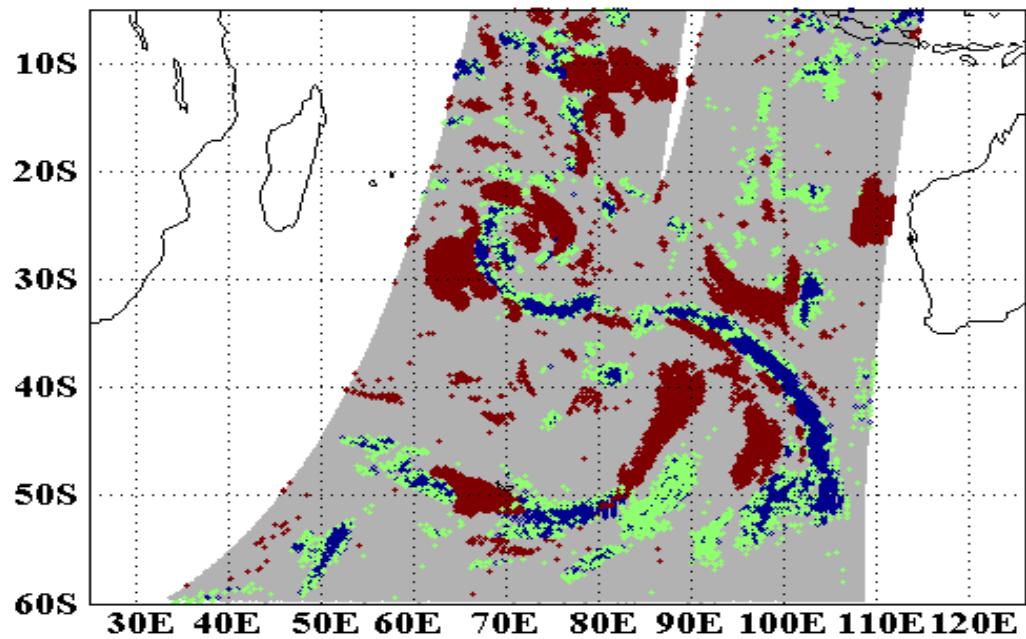
Questions

1. What might be responsible for the **positive biases** found in **channel 3** provided by both FY-3A/MWHS and NOAA-18/MHS instruments?

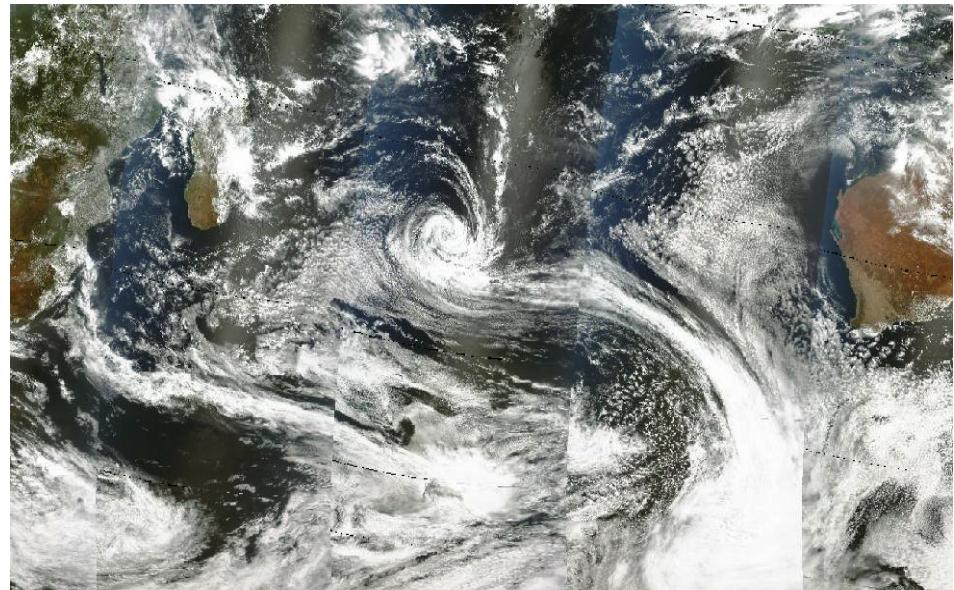
2. What might have caused the **negative biases** of **channels 4 and 5 over land** provided by both FY-3A/MWHS and NOAA-18/MHS instruments?

Negative
Outliers
Positive

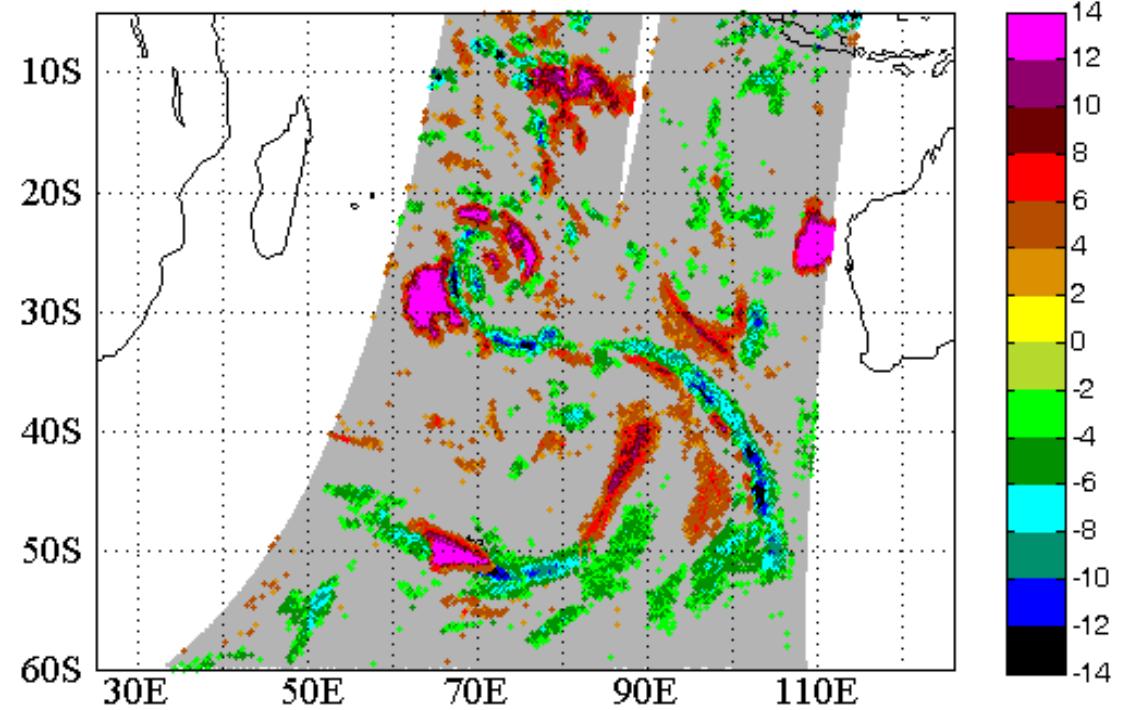
FY-3A MWHS Ch3



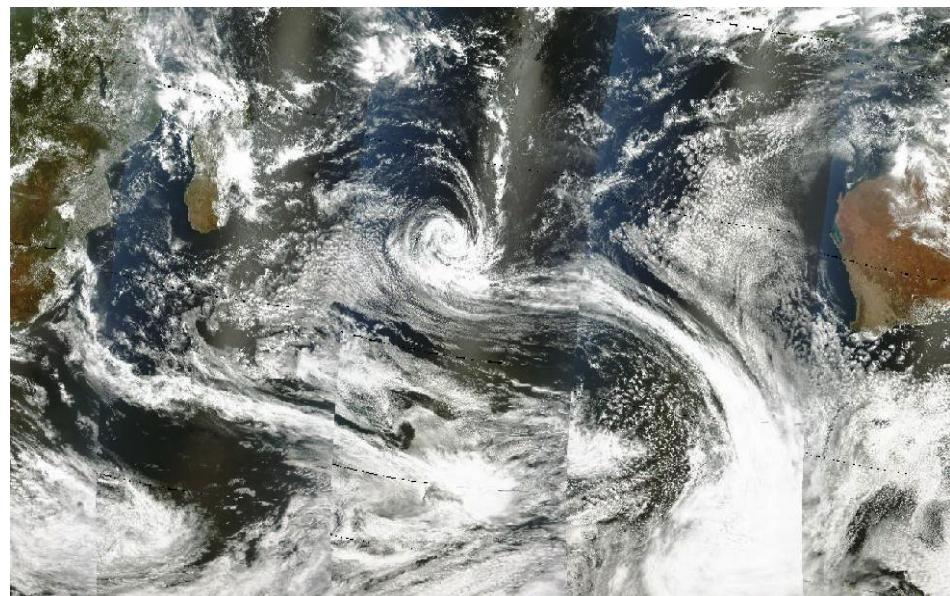
Clouds
Clear Streaks
Seen from FY-3A MERSI



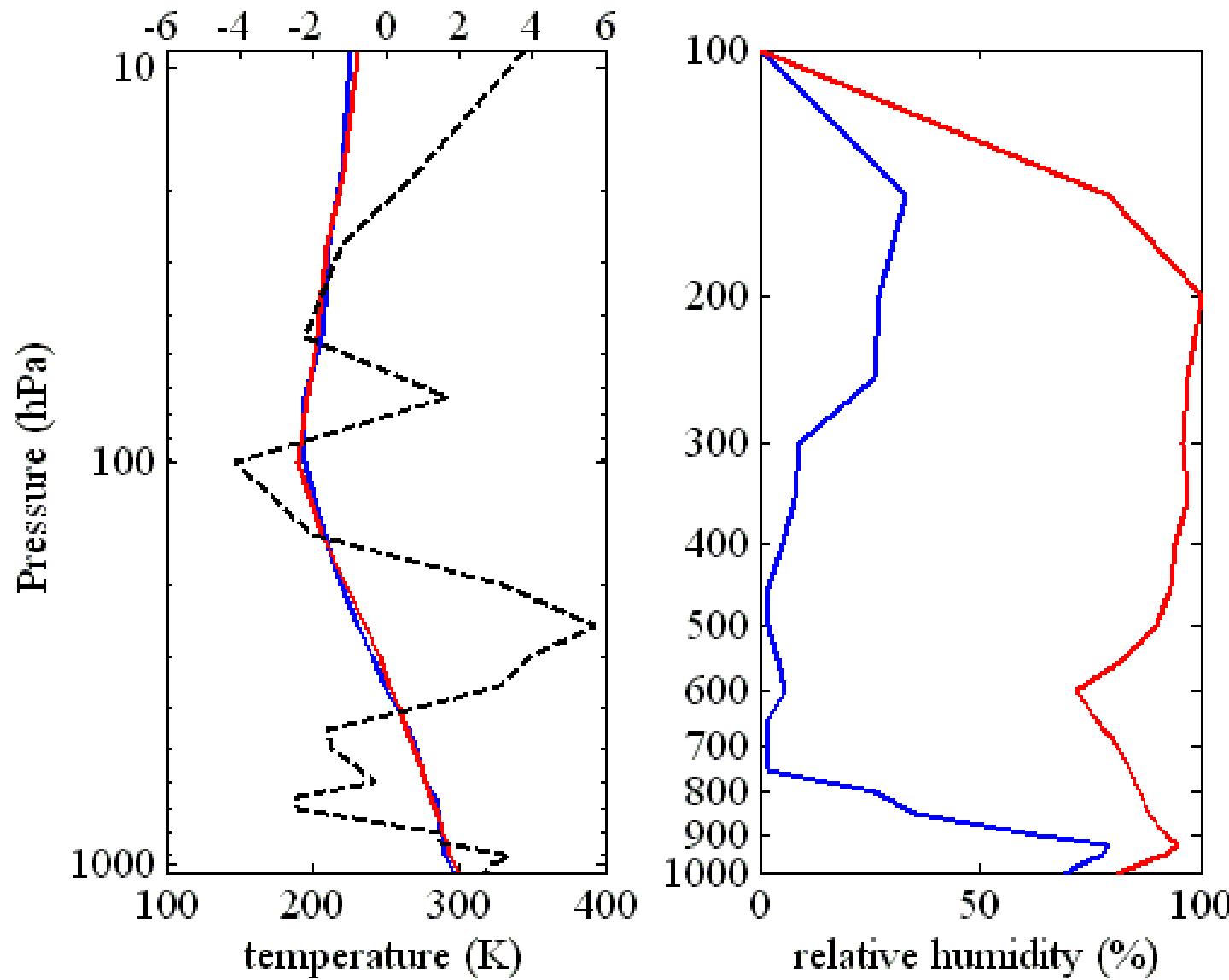
**O-B Values of
Outliers**
FY-3A MWHS Ch3



Clouds
Clear Streaks
Seen from FY-3A MERSI



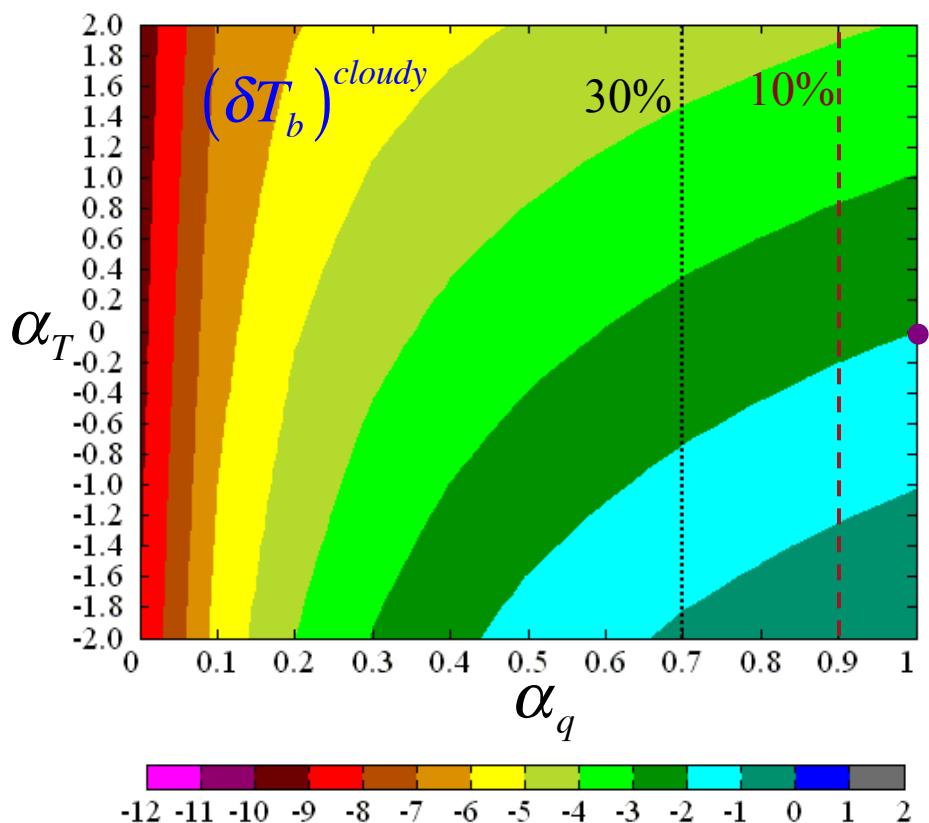
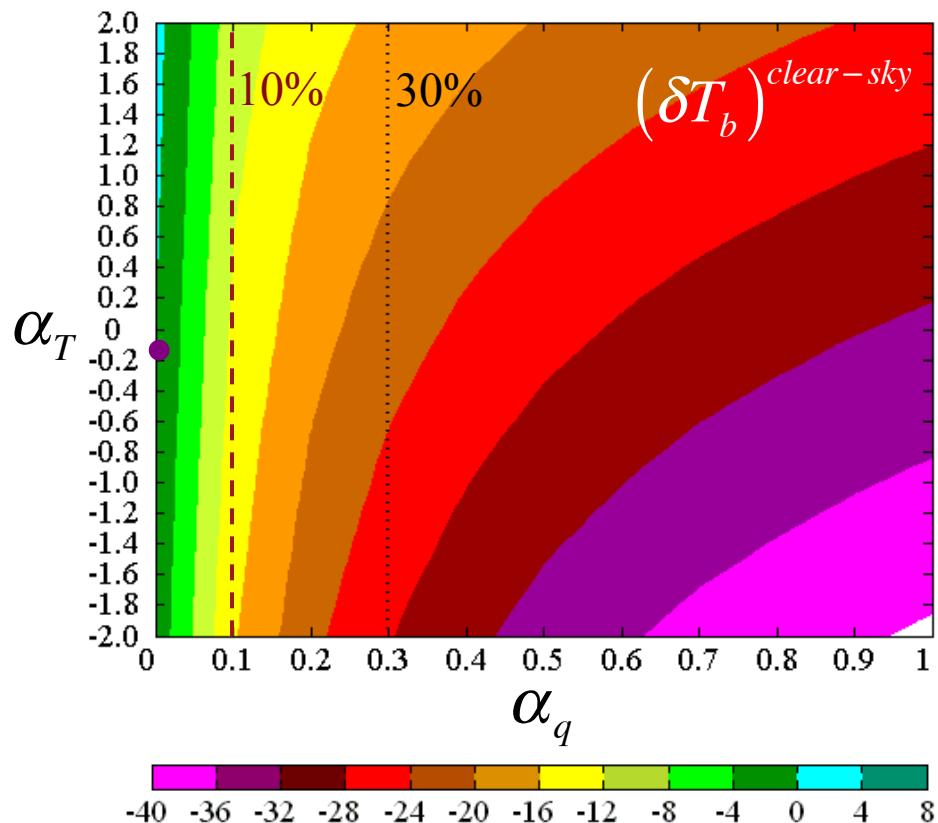
Cloudy and Clear-Sky Profiles



Sensitivity Test

$$(\delta T_b)^{clear-sky} = H(T^{clear-sky} + \alpha_T \Delta T, q^{clear-sky} + \alpha_q \Delta q) - T_b^{clear-sky}$$

$$(\delta T_b)^{cloudy} = H(T^{clear-sky} + (1 - \alpha_T) \Delta T, q^{clear-sky} + (1 - \alpha_q) \Delta q) - T_b^{cloud}$$



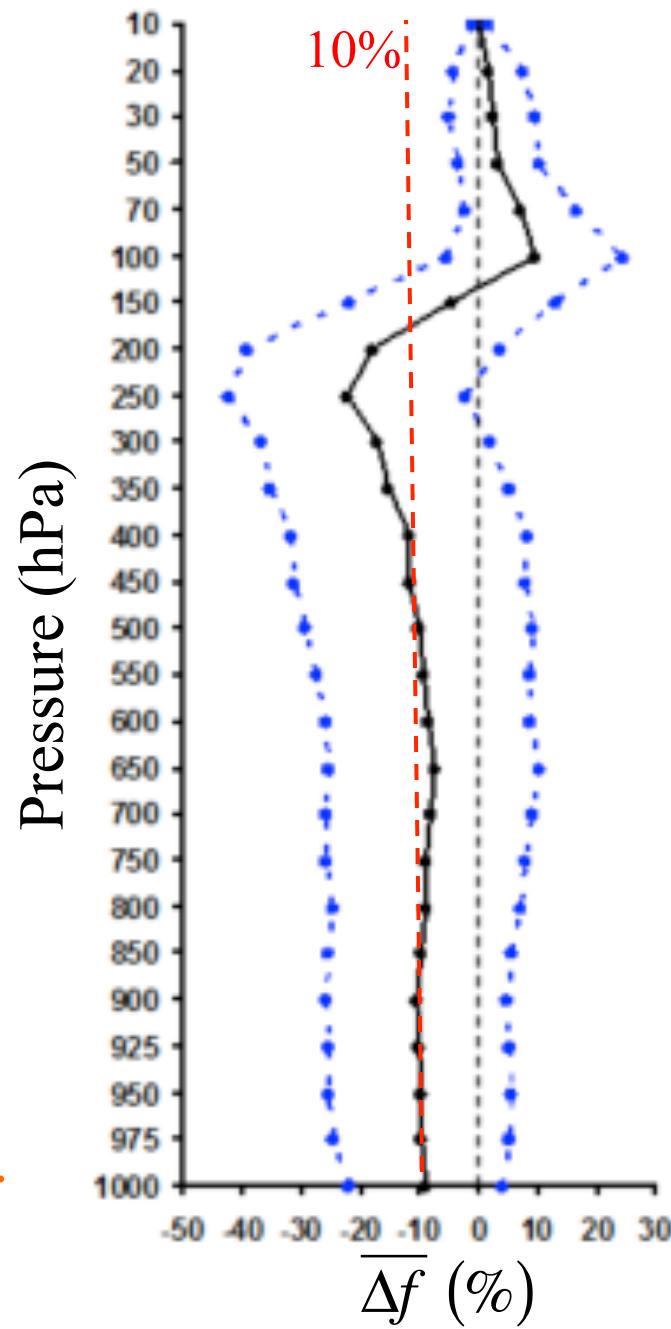
Relative Humidity

Differences between GPS RO
and NCEP GFS FNL:

$$\overline{\Delta f} = \frac{1}{1631} \sum_{i=1}^{1631} (f_i^{GPS} - f_i^{NCEP})$$

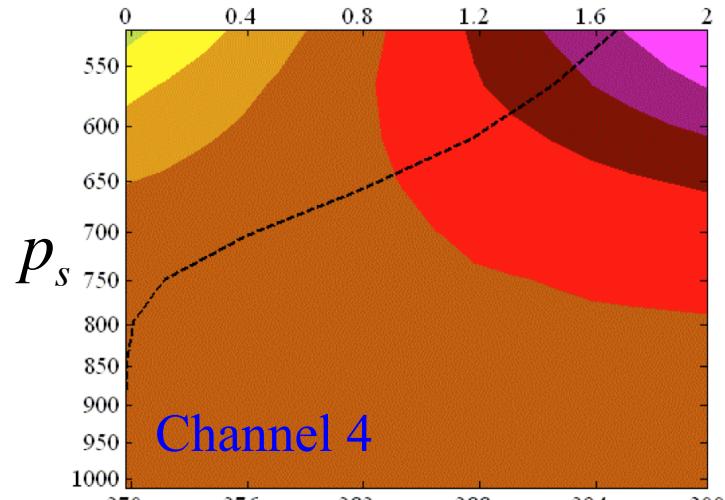
Data during January 2010

A wet bias in NCEP GFS analyses.

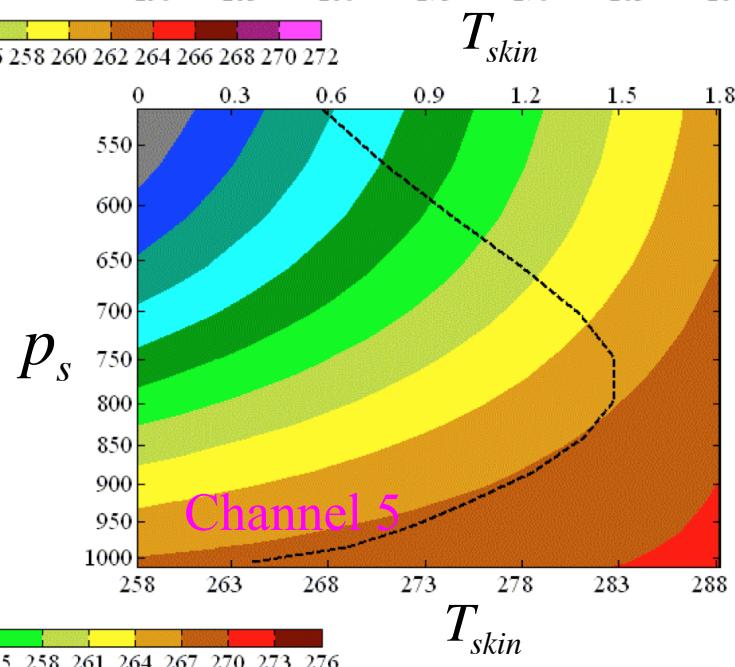
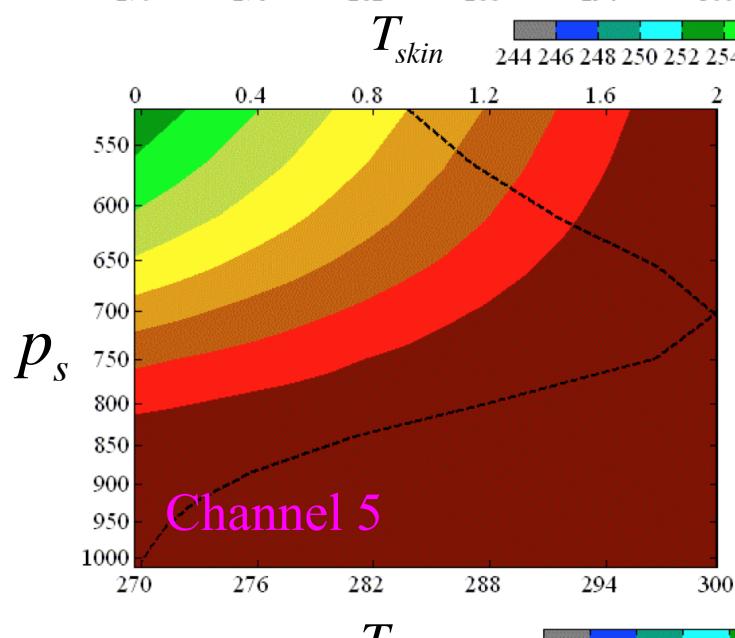
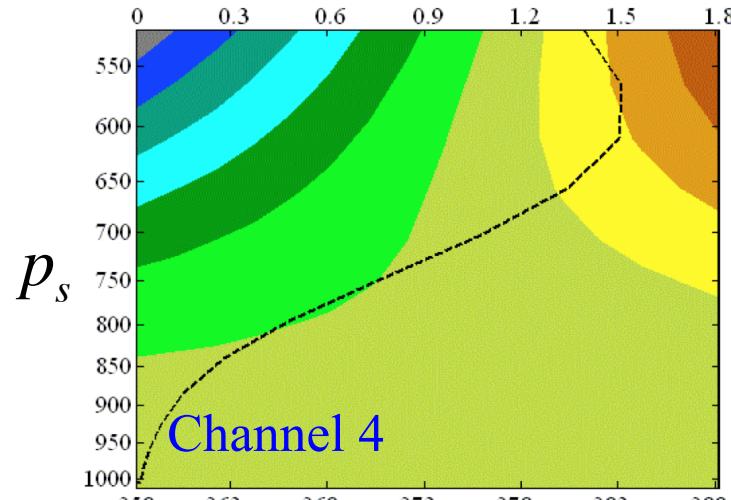


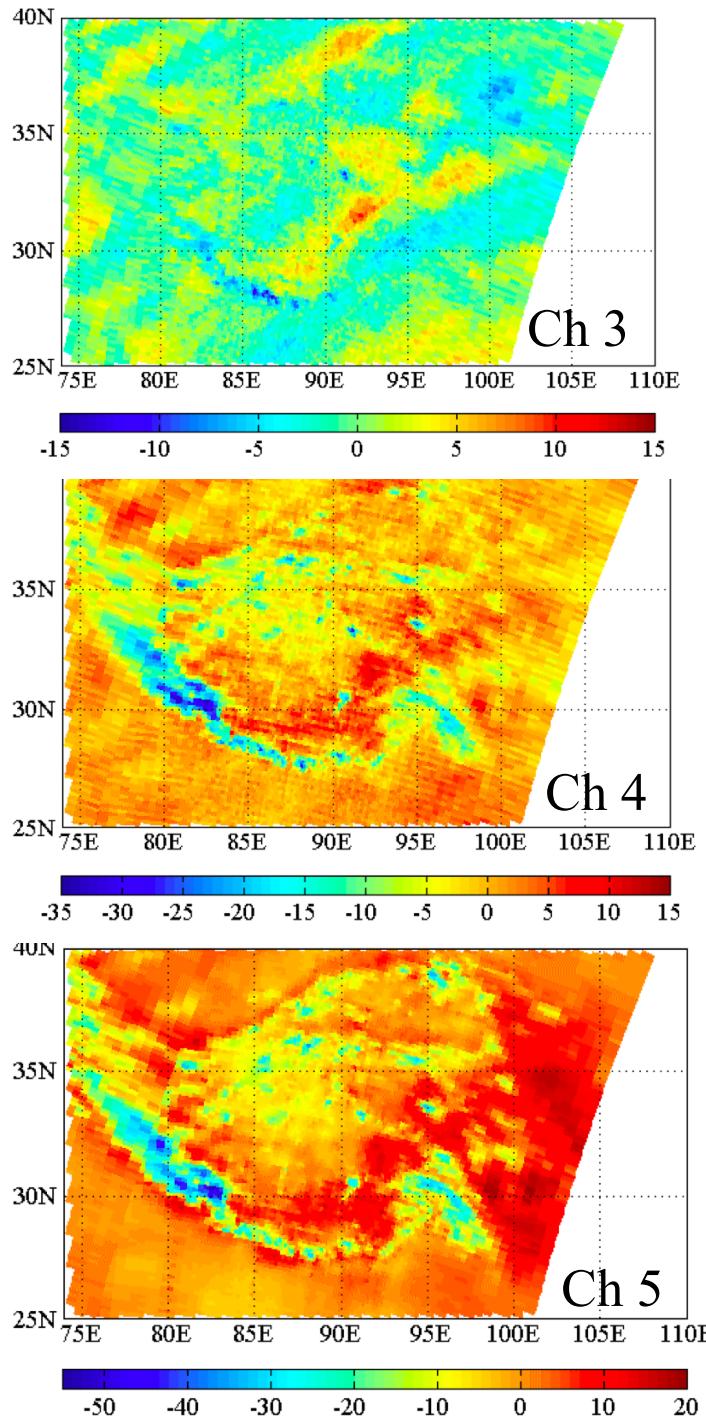
Sensitivity to Surface Pressure

Wet Profile

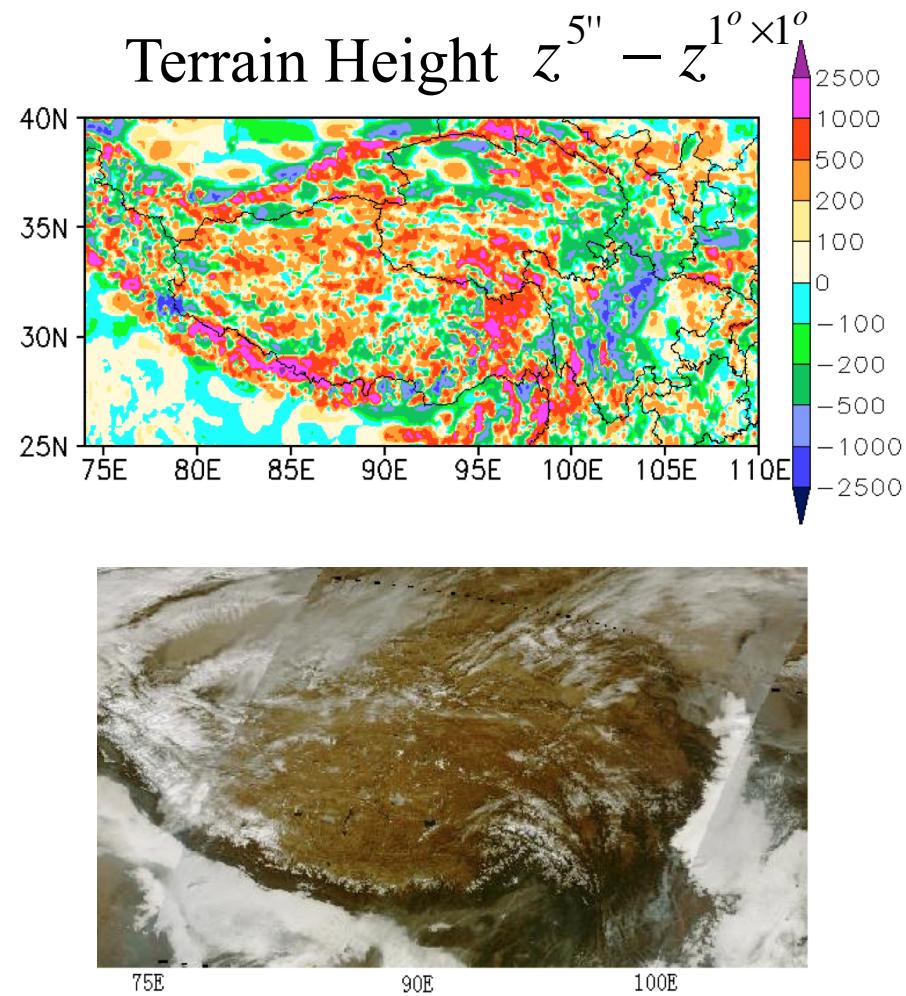


Drier Profile



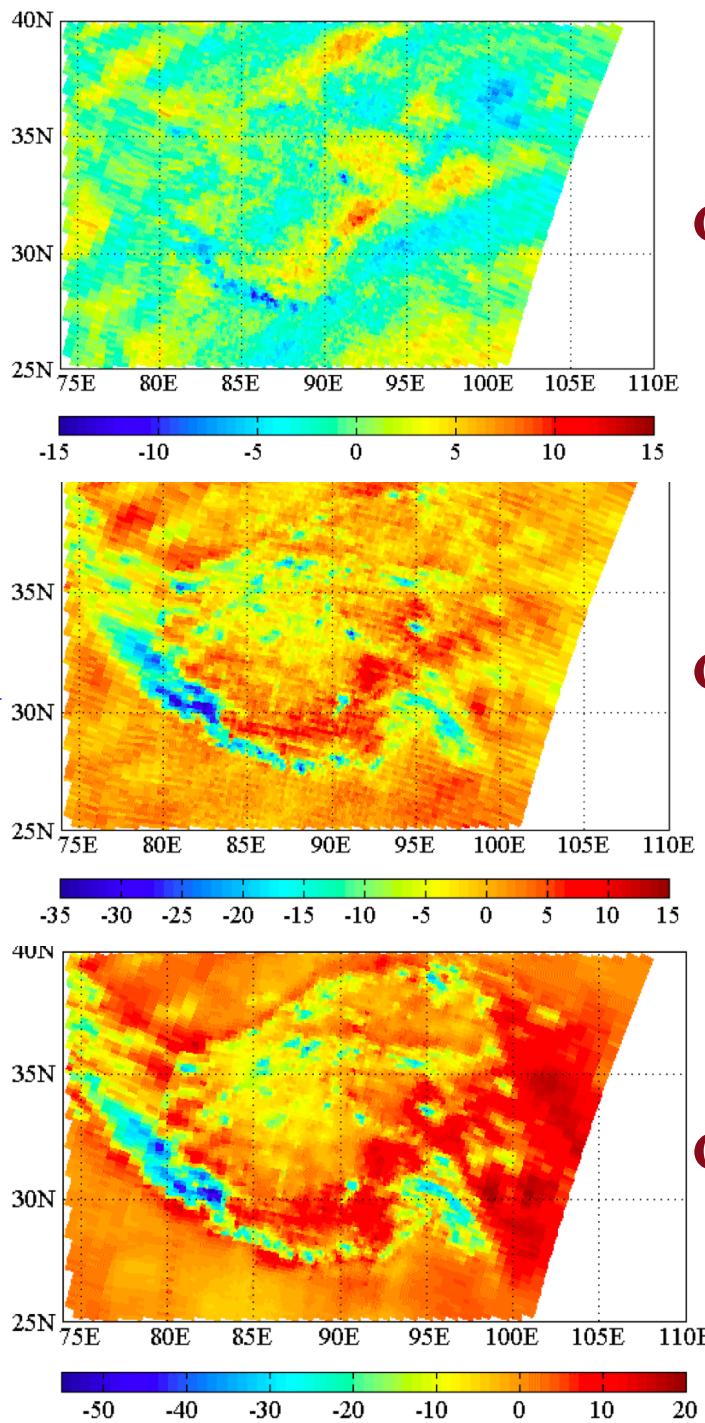


Brightness Temperatures provided by FY-3A MWHS over Tibetan Plateau

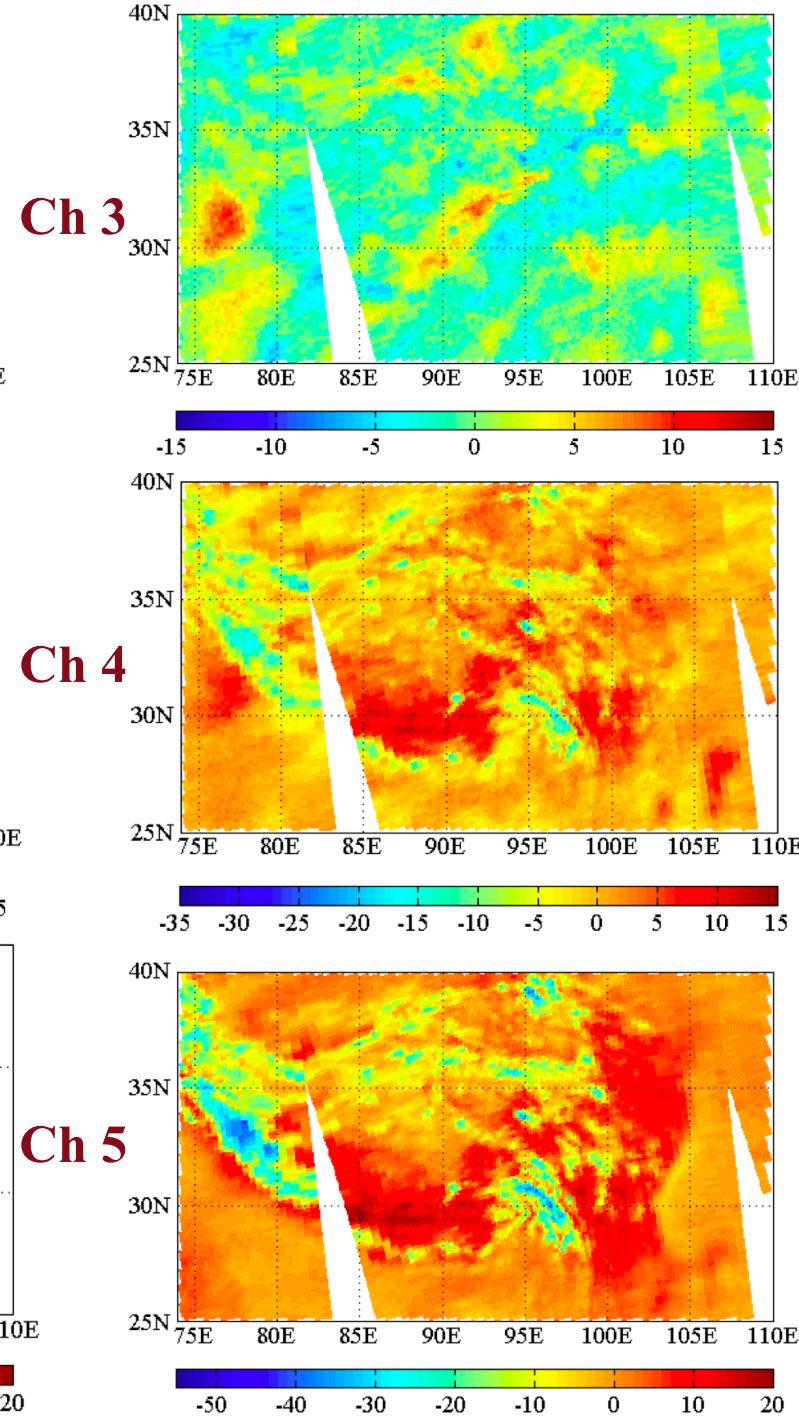


0300-0900 UTC January 18, 2010

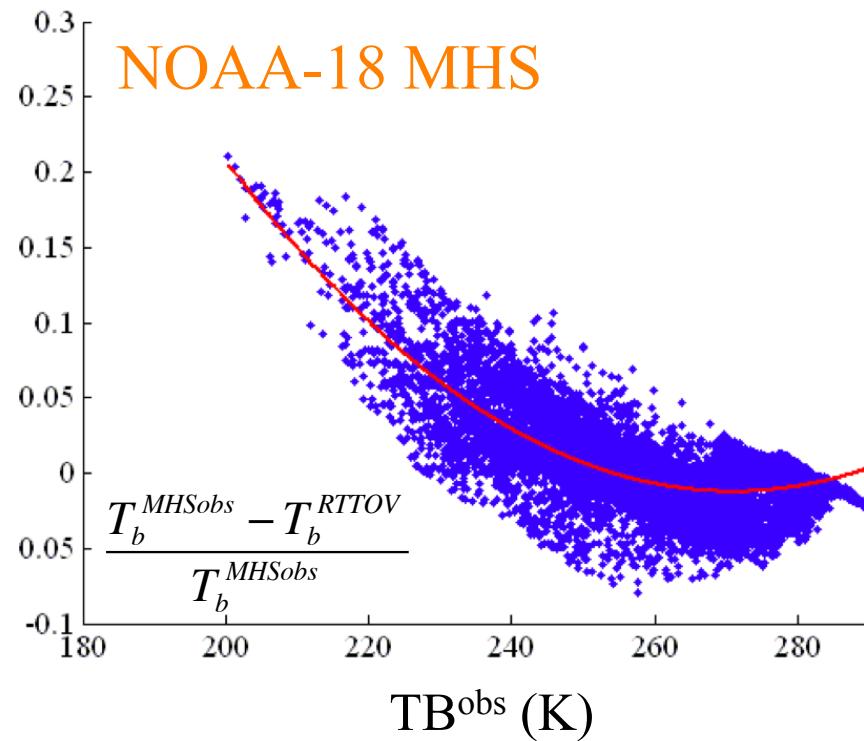
FY-3A



Ch 4



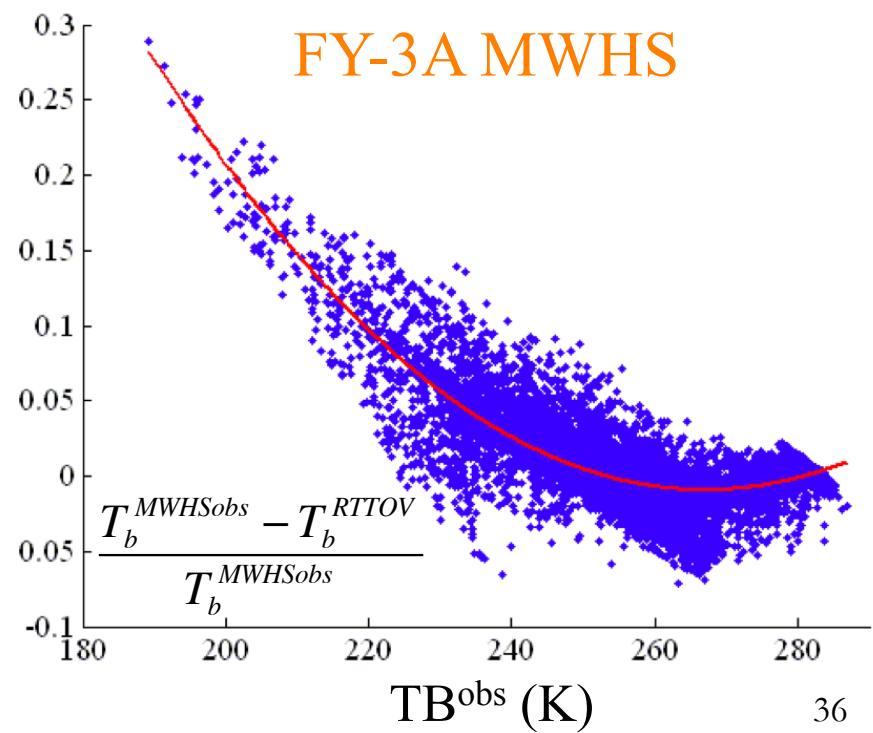
NOAA18

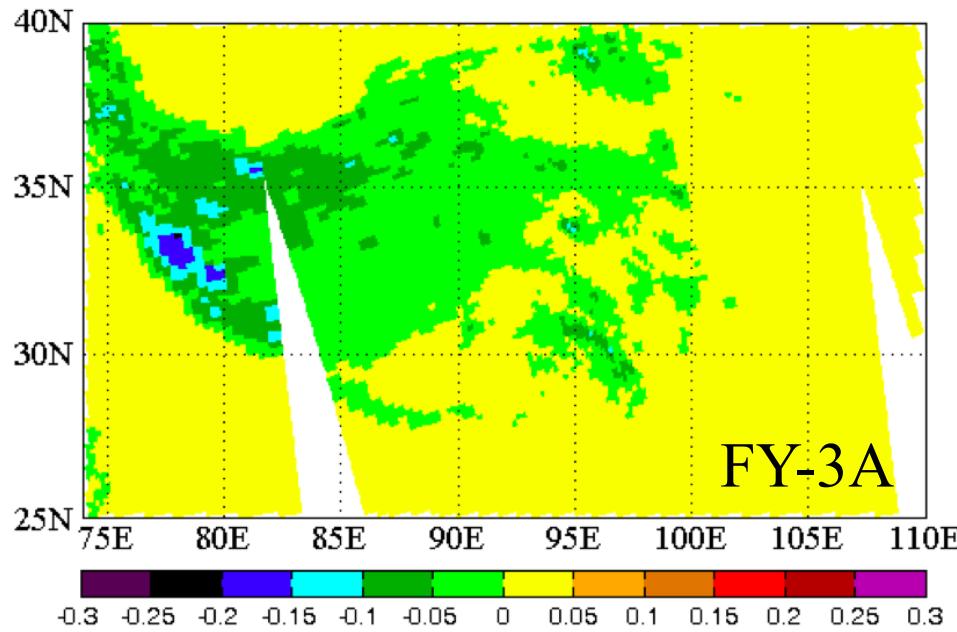


**Scatter plots of (O-B)/O
Channel 5
0300-0900 UTC 01/18/2010**

$$\Delta T_b \approx \Delta \varepsilon T_s$$

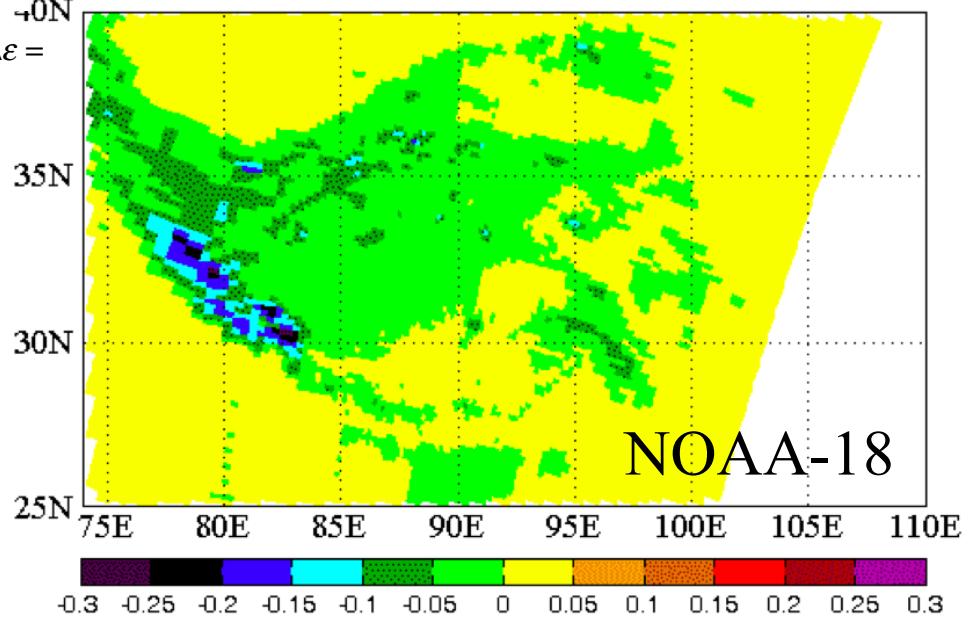
$$\Delta \varepsilon \approx \frac{\Delta T_b}{T_s}$$





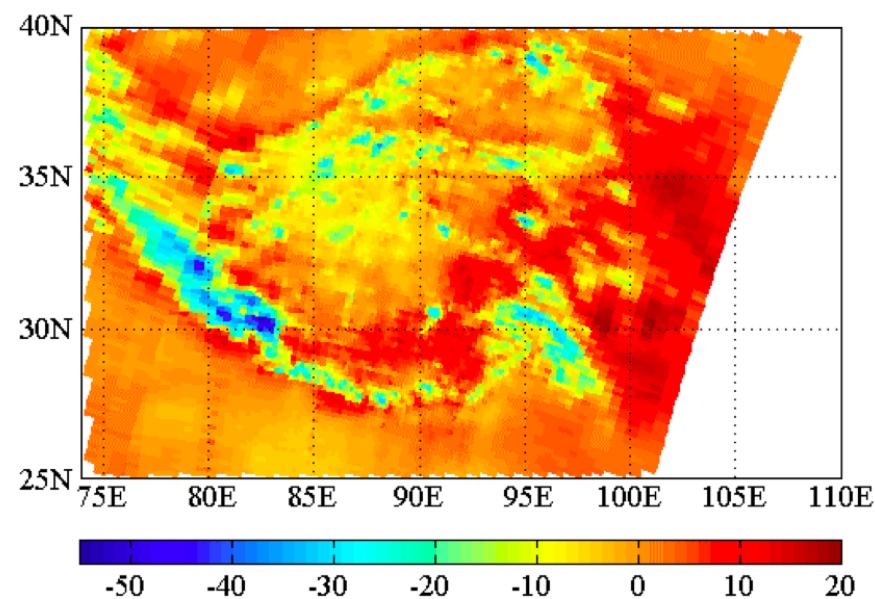
“Emissivity Correction” Channel 5

$$\Delta\epsilon = 4.810 \times 10^{-5} T_b^2 - 2.570 \times 10^{-2} T_b + 3.423$$

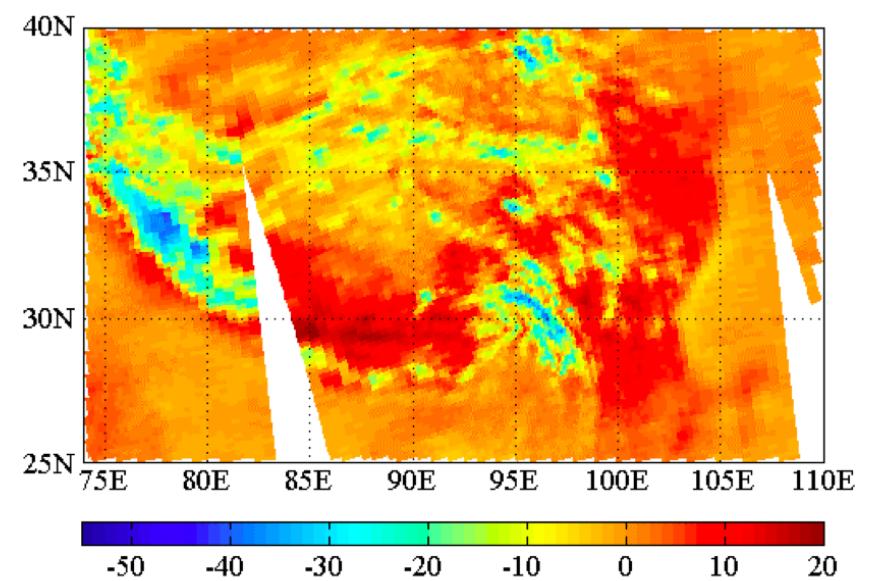


$$\Delta\epsilon = 4.359 \times 10^{-5} T_b^2 - 2.360 \times 10^{-2} T_b + 3.190$$

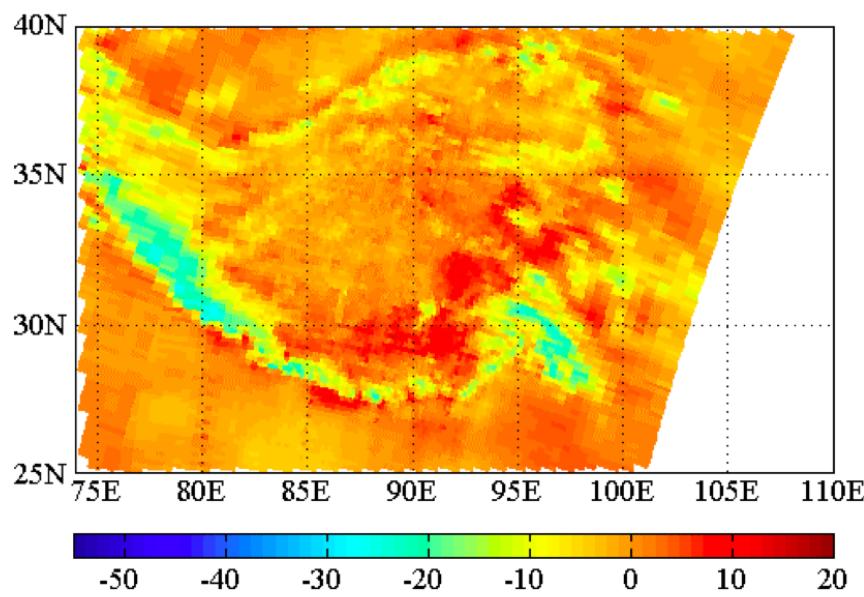
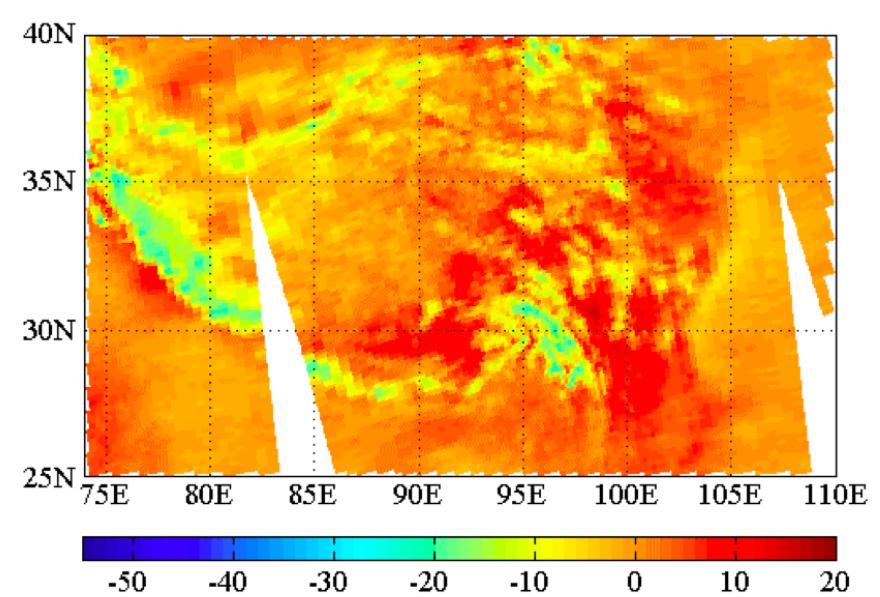
FY-3A



Ch 5



NOAA18



Part III

Comparison between AMSU-A and MWTS

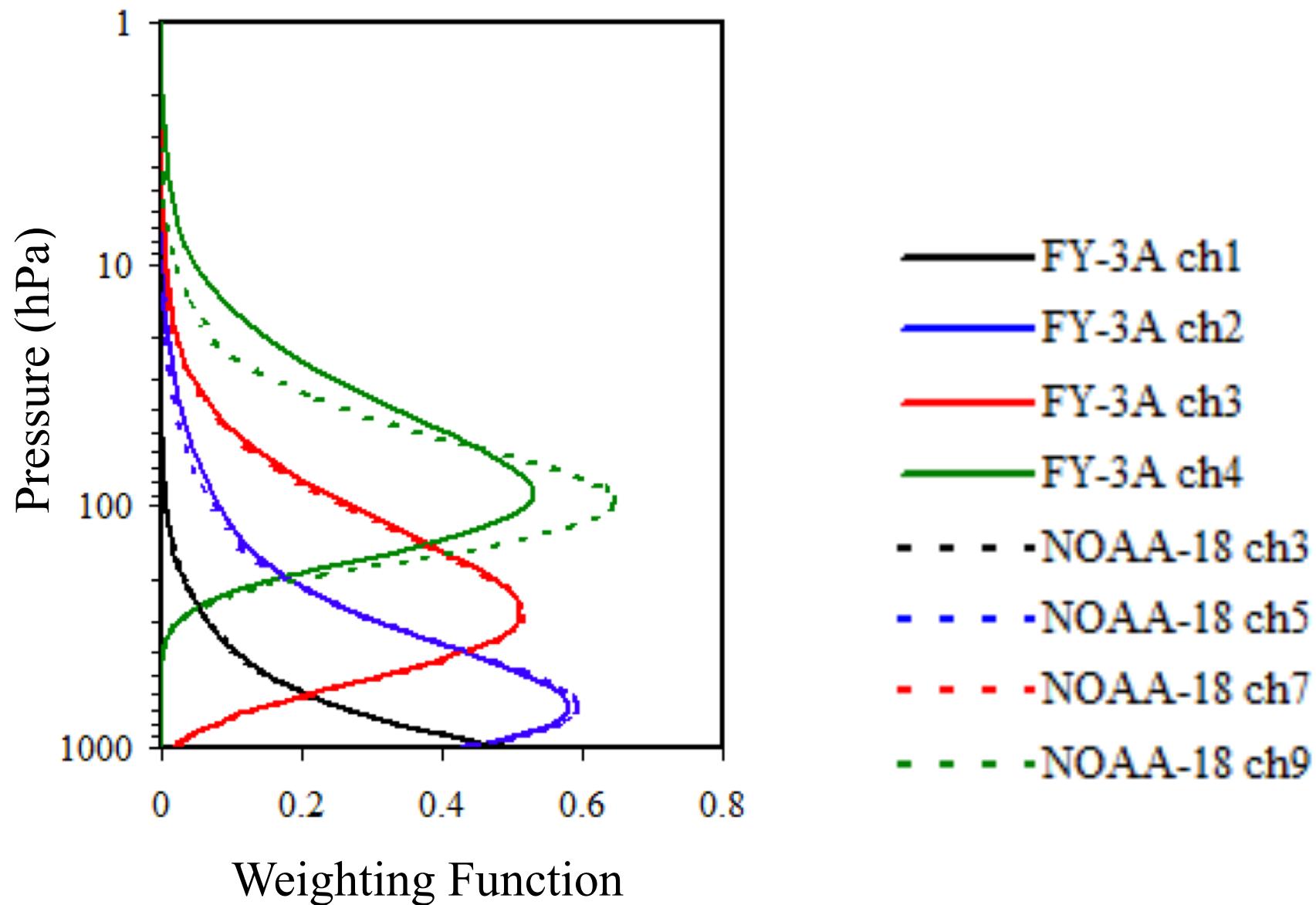
- ✓ Global and scan biases
- ✓ Scene-temperature dependence
of MWTS biases
- ✓ Root-cause analysis of MWTS
biases

Comparison of Instrument Parameters between AMSU-A and MWTS

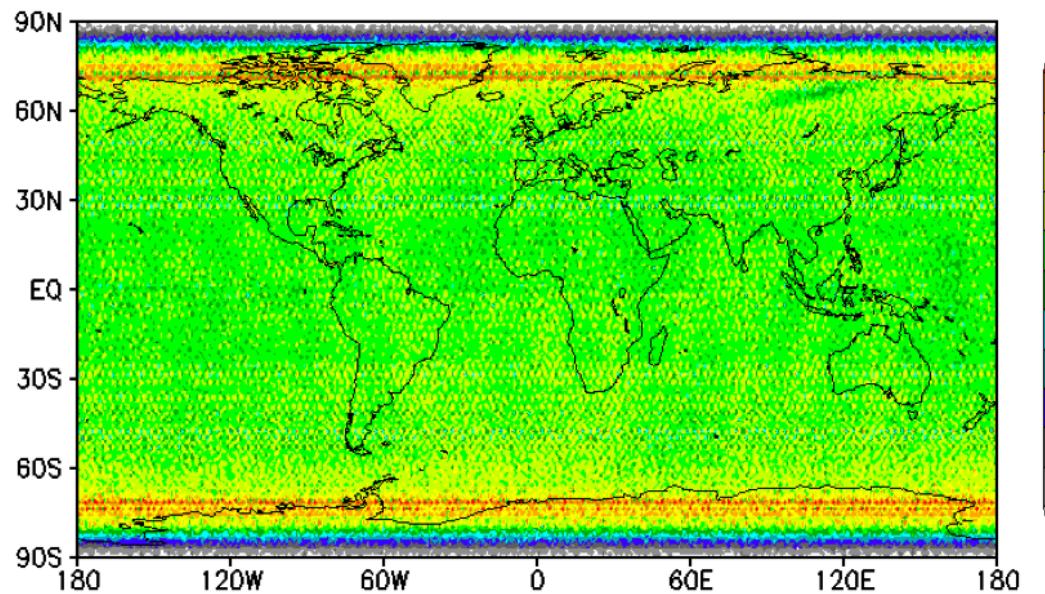
Channel number		Frequency (GHz)		Bandwidth (MHz)		NEΔT (K)	
AMSU-A	MWTS	AMSU-A	MWTS	AMSU-A	MWTS	AMSU-A	MWTS
3	1	50.30		180		0.40	0.5
5	2	53.596±0.115		2×170		0.25	0.4
7	3	54.94		400		0.25	0.4
9	4	57.29		330		0.25	0.4

Channel number		Nadir Res. (km)		WF (hPa)		Swath width (km)	
AMSU-A	MWTS	AMSU-A	MWTS	AMSU-A	MWTS	AMSU-A	MWTS
3	1	48	62	surface	surface	2300	2250
5	2	48	62	700	700	2300	2250
7	3	48	62	270	300	2300	2250
9	4	48	62	90	70	2300	2250

Weighting Functions

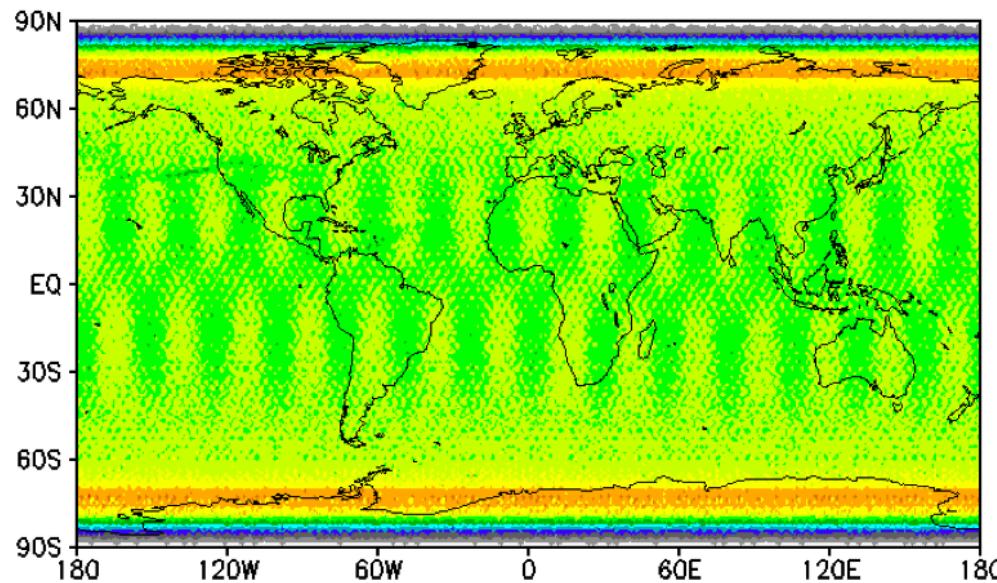


FY-3A MWHS



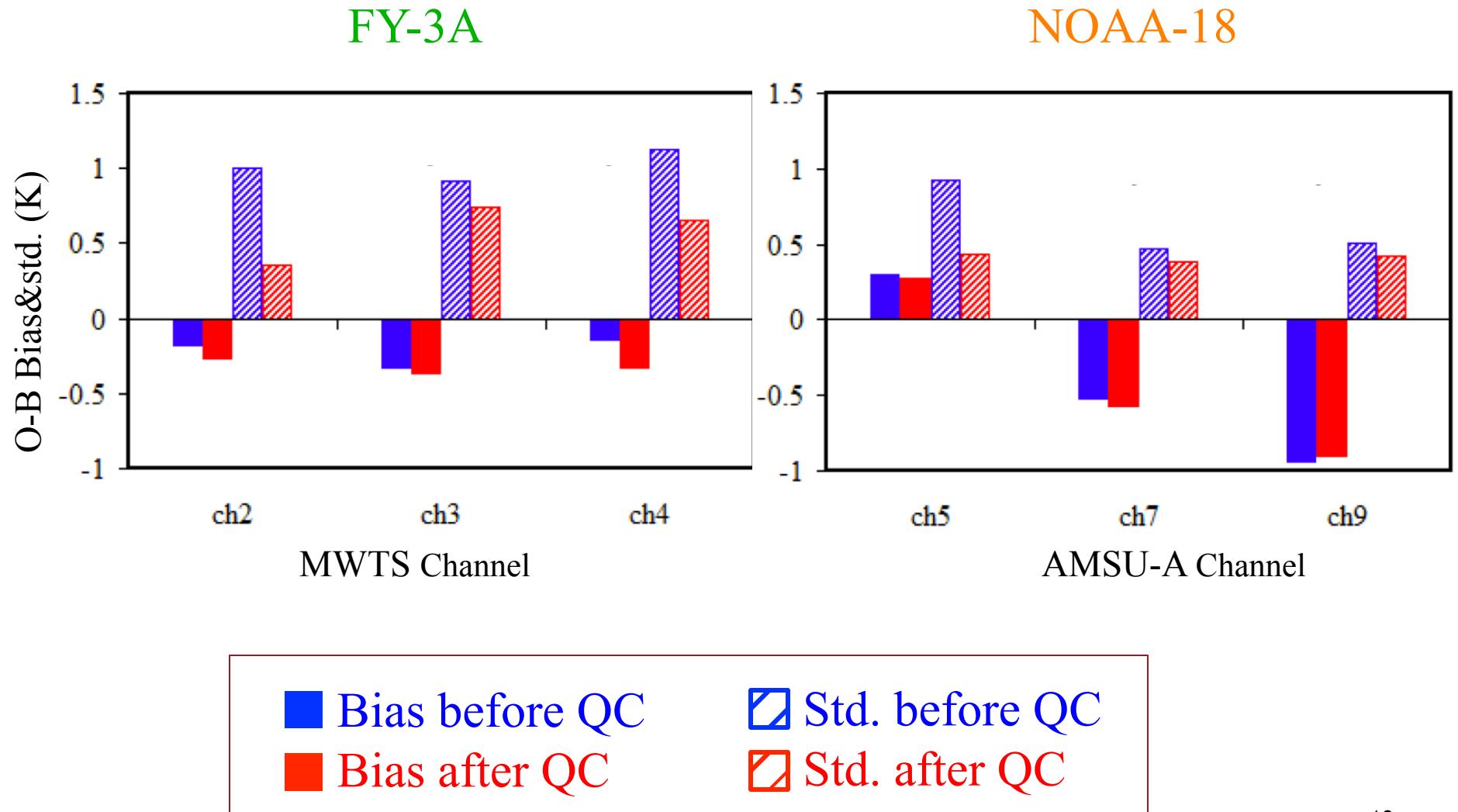
**Monthly Total
Number of
Observations in
 $1^{\circ} \times 1^{\circ}$ Grid Boxes**

NOAA-18 AMSU-A

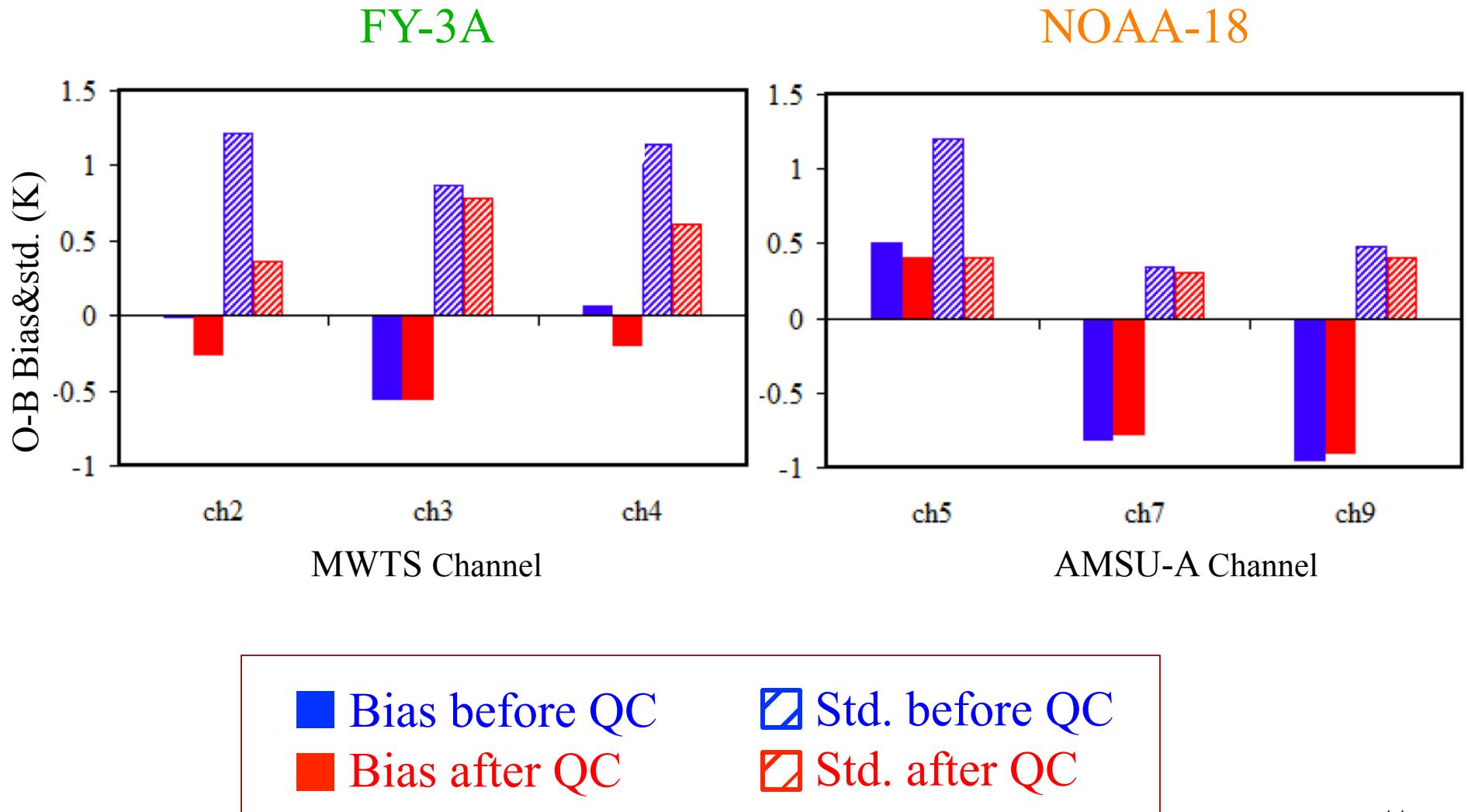


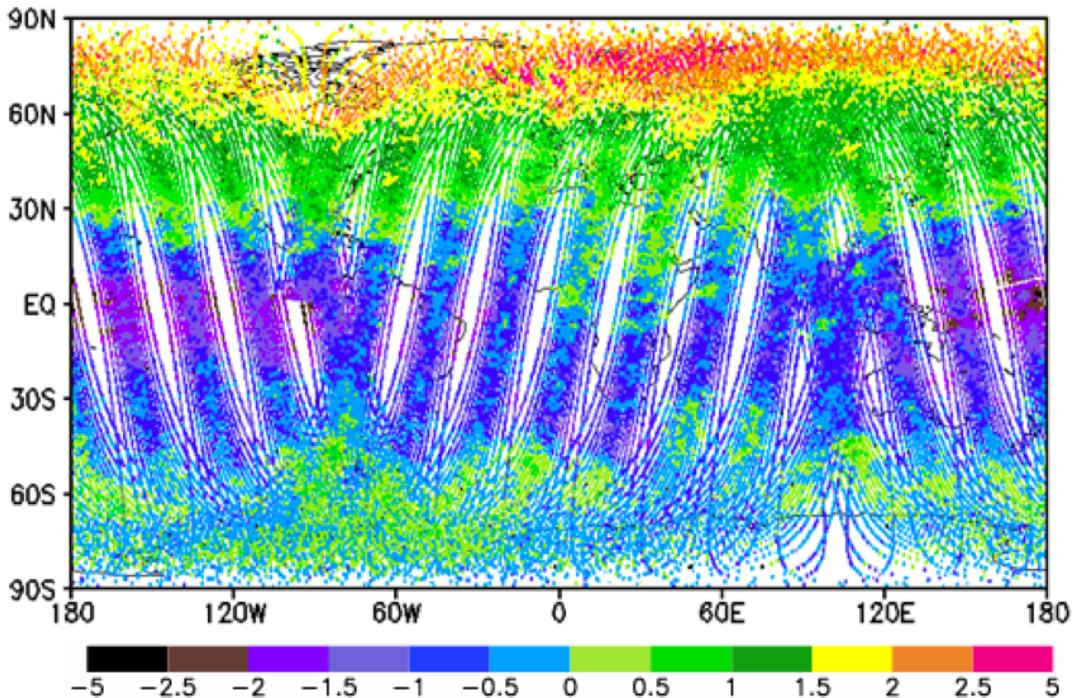
AMSU-A obs. is
about 4 times more
than MWTS obs.

Biases & Standard Deviations



Nadir Only Biases & Standard Deviations



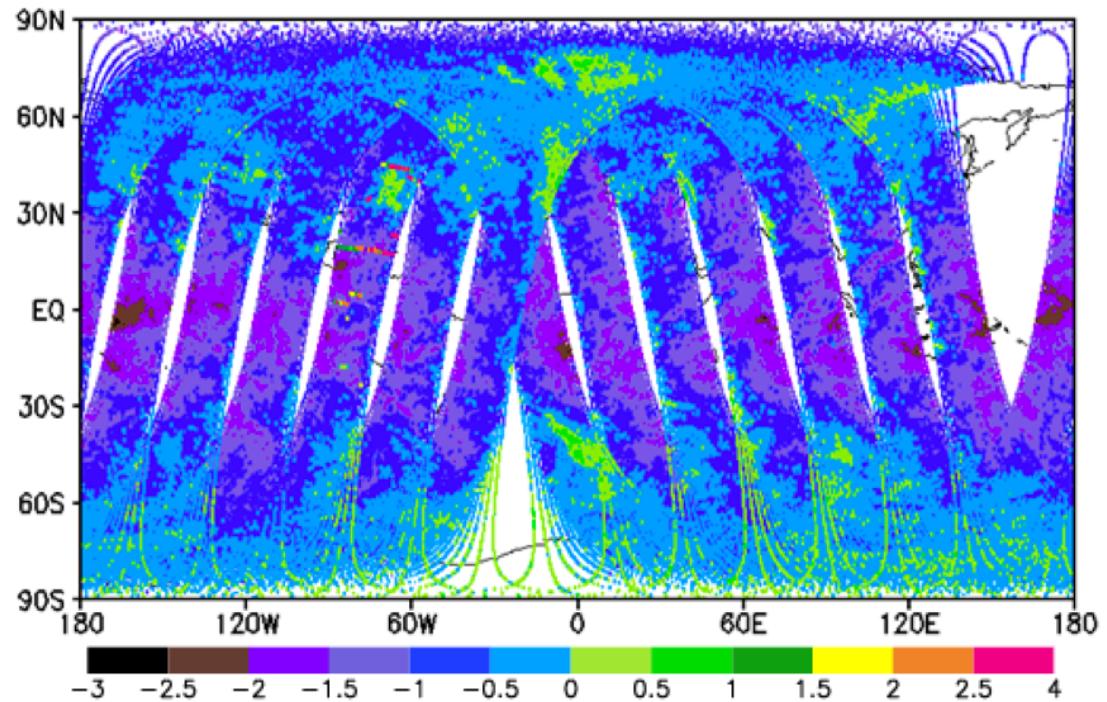


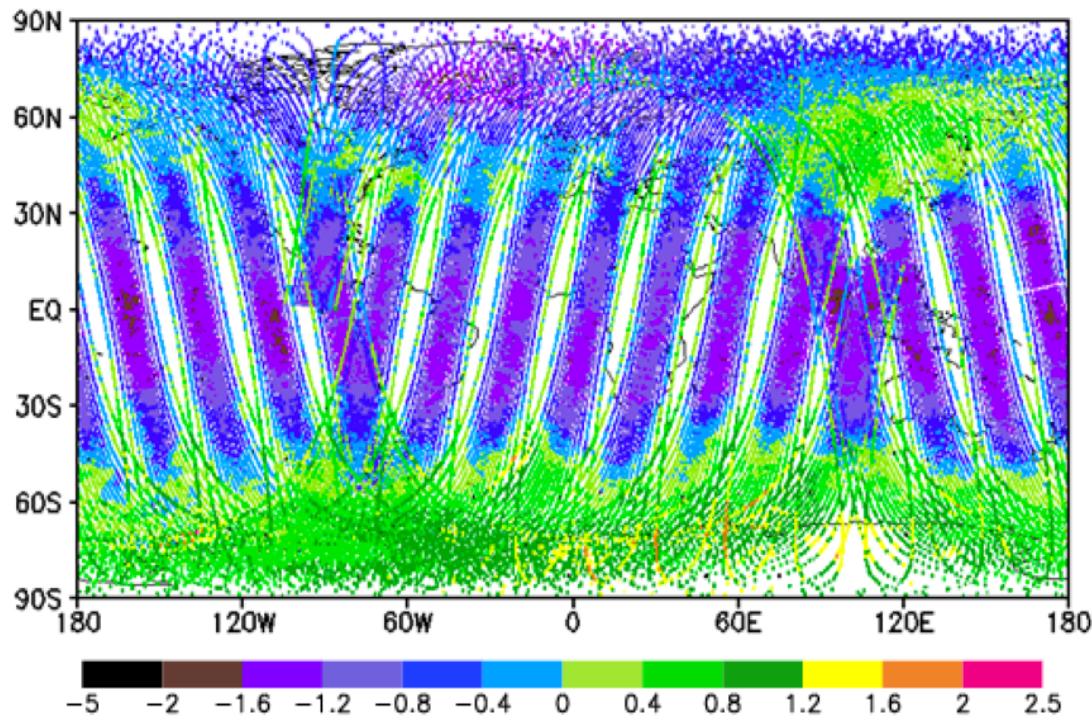
MWTS Ch4

O – B

**0300UTC-1500 UTC
January 2, 2010**

AMSU-A Ch9



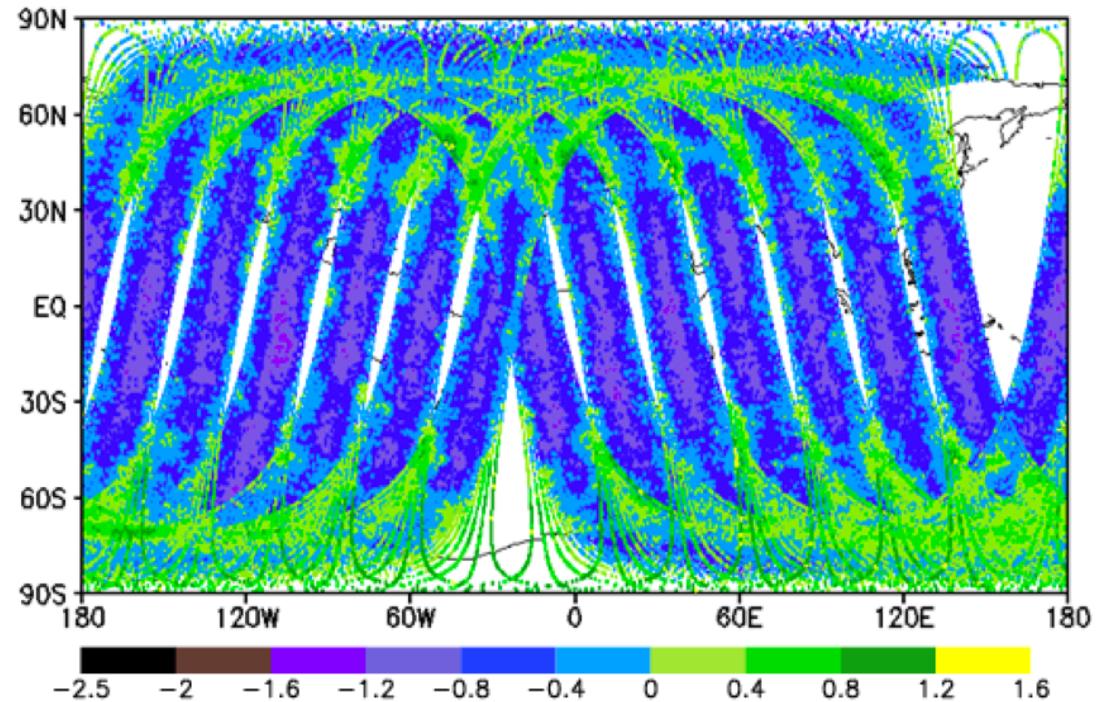


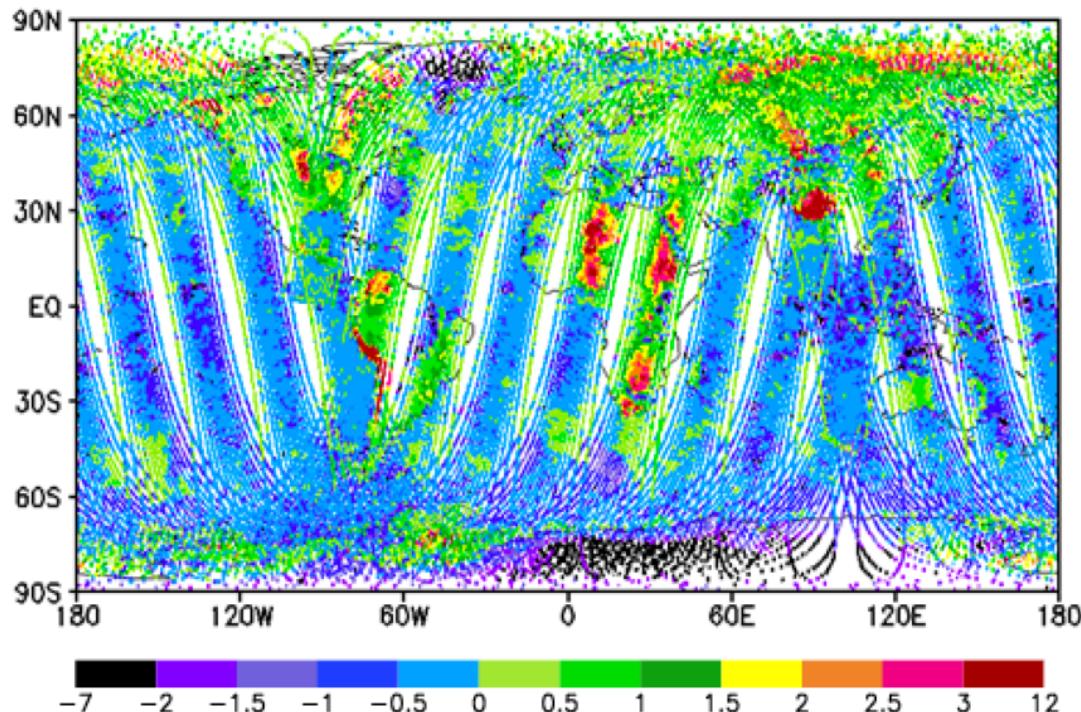
FY-3A Ch3

O – B

**0300UTC-1500 UTC
January 2, 2010**

AMSU-A Ch7

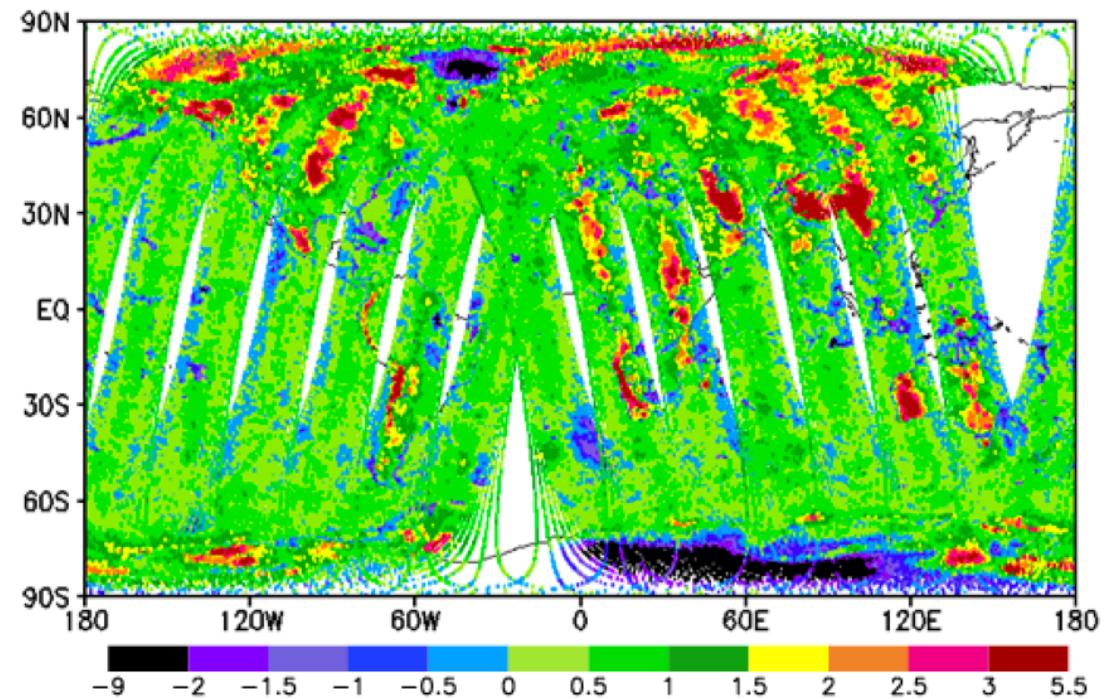




O – B

**0300UTC-1500 UTC
January 2, 2010**

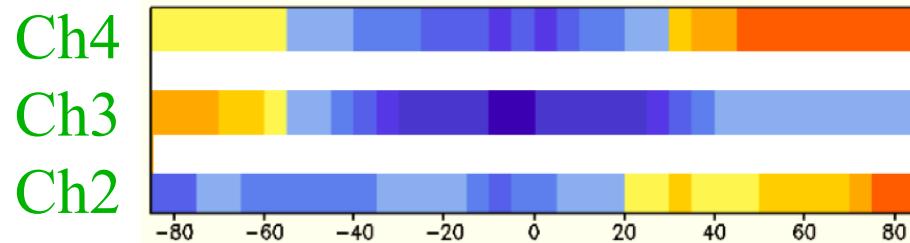
AMSU-A Ch5



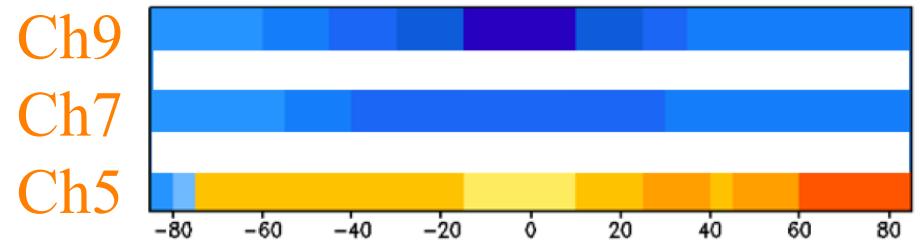
Latitudinal Dependence of Bias

All Data

FY-3A MWTS

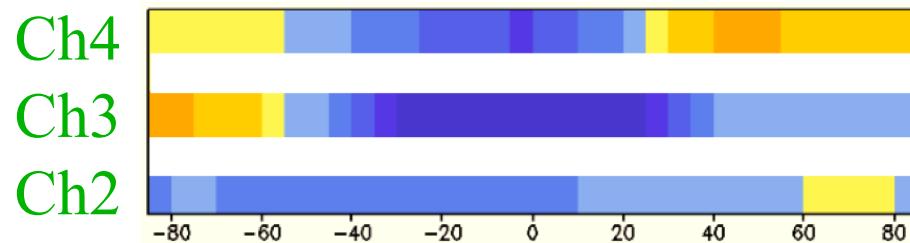


NOAA-18 AMSU-A

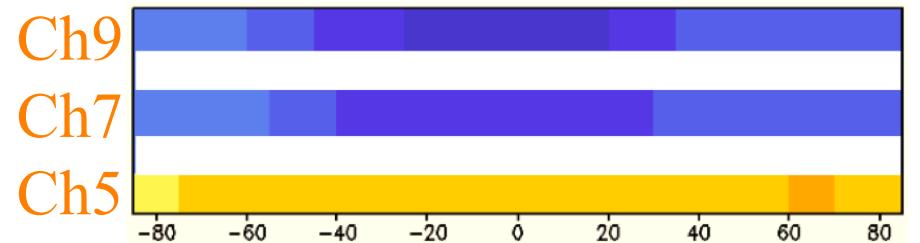


After QC

FY-3A MWTS



NOAA-18 AMSU-A



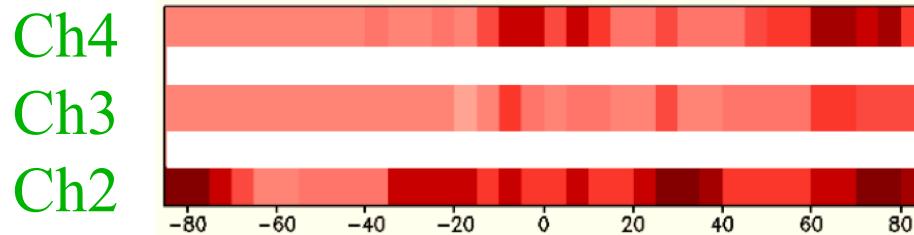
48



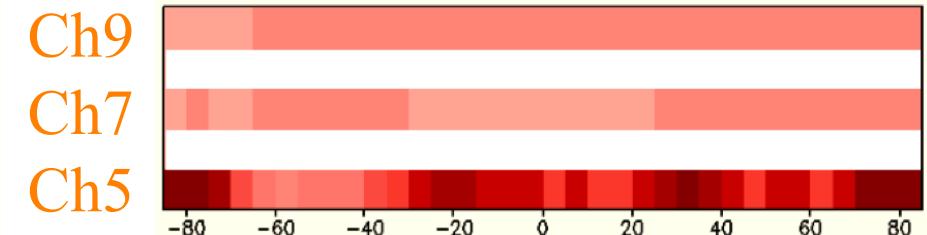
Latitudinal Dependence of Std.

All Data

FY-3A MWTS

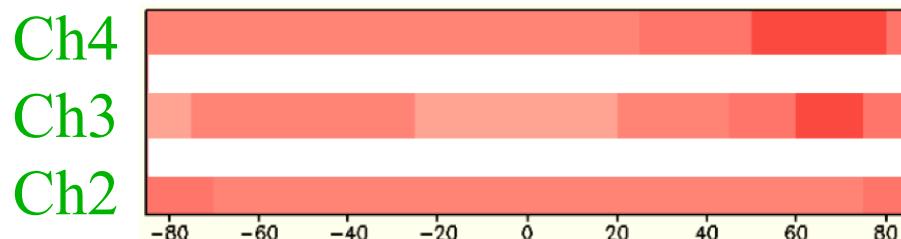


NOAA-18 AMSU-A

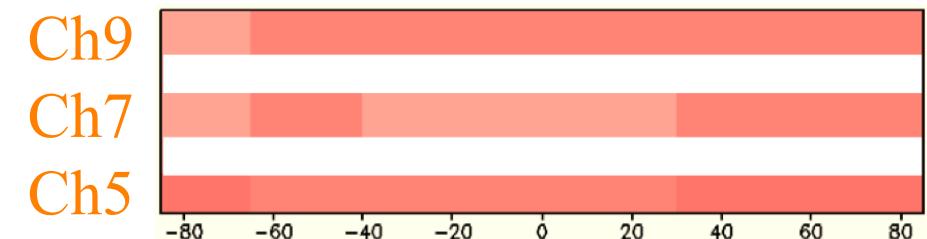


After QC

FY-3A MWTS

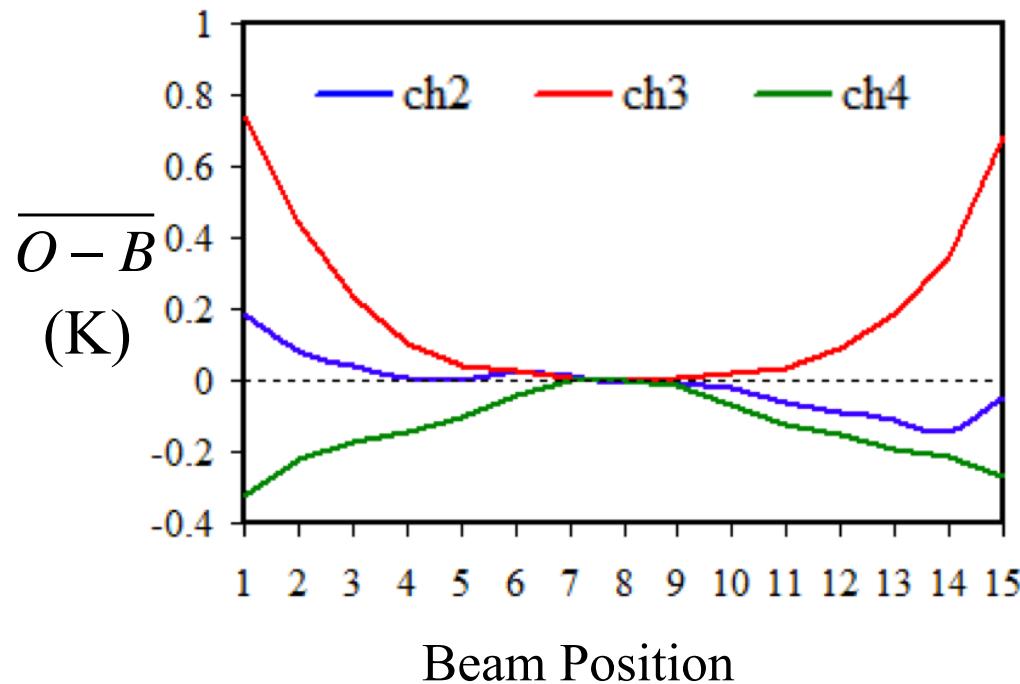


NOAA-18 AMSU-A

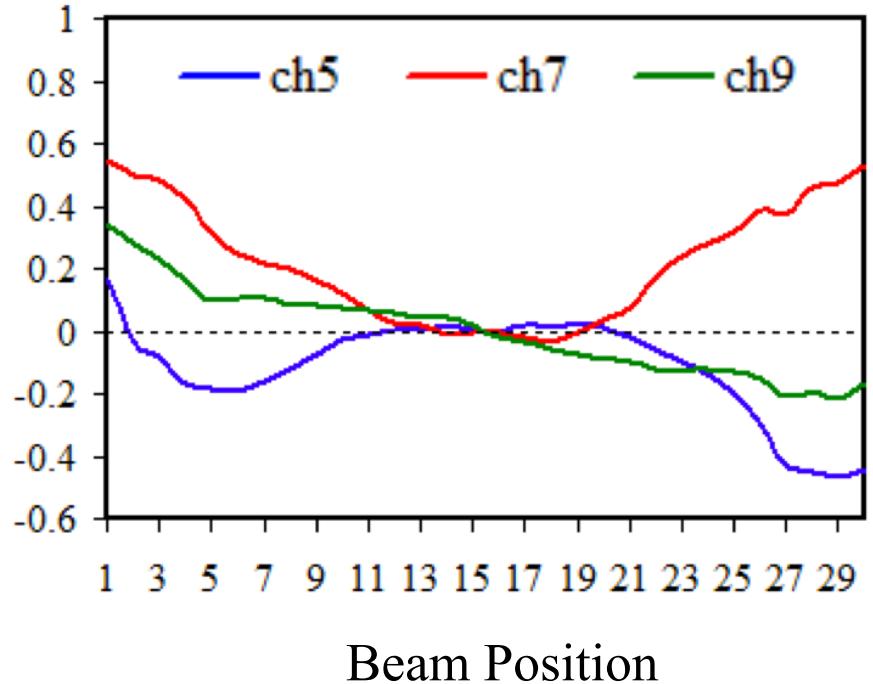


Scan Bias

FY-3A MWTS Ch2

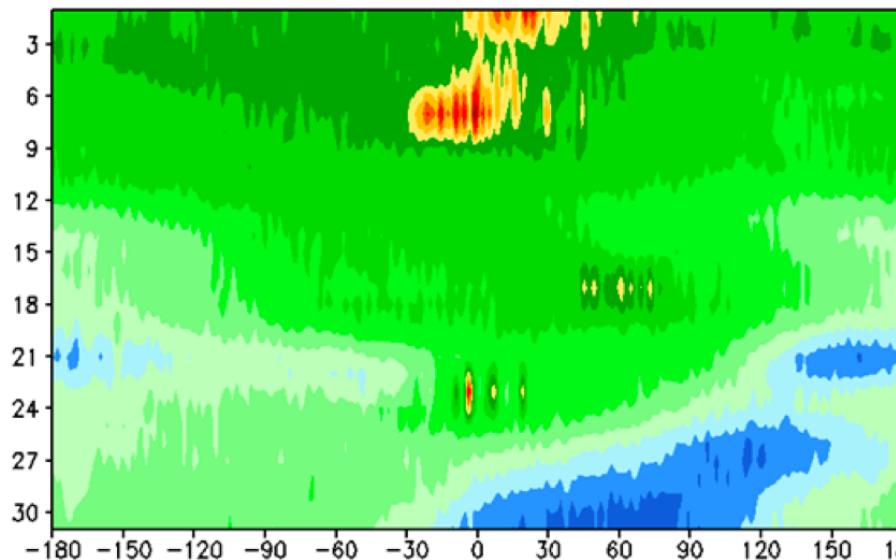


NOAA-18 AMSU-A Ch5

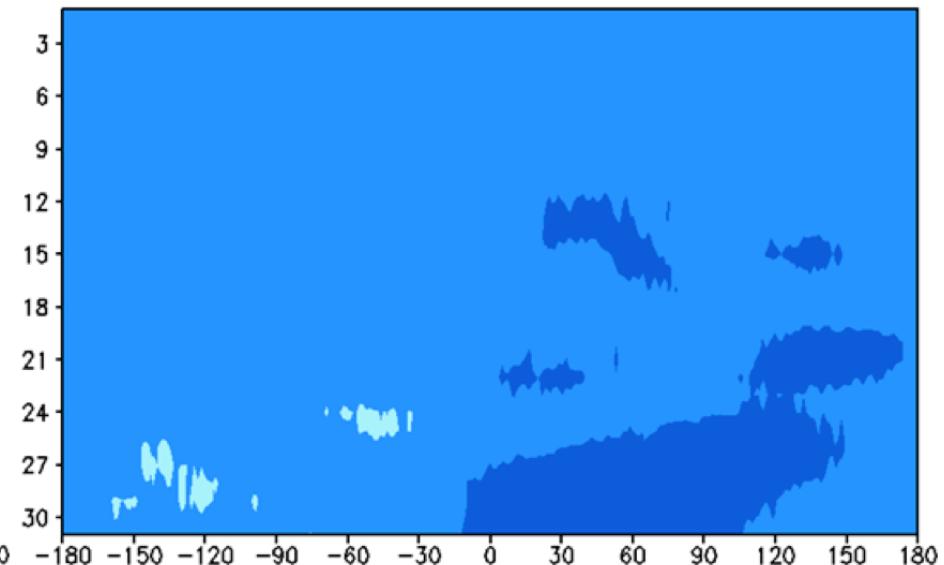


Weather-Dependence of MWTS Bias (O-B) in Northern Polar Region (78.5N-81.5N)

MWTS Ch4

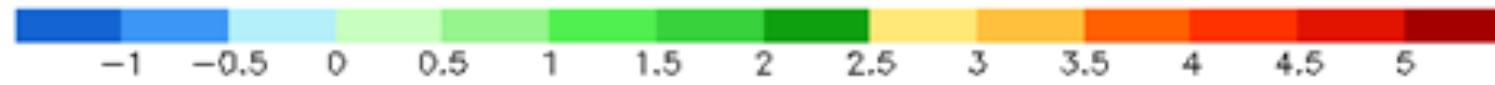


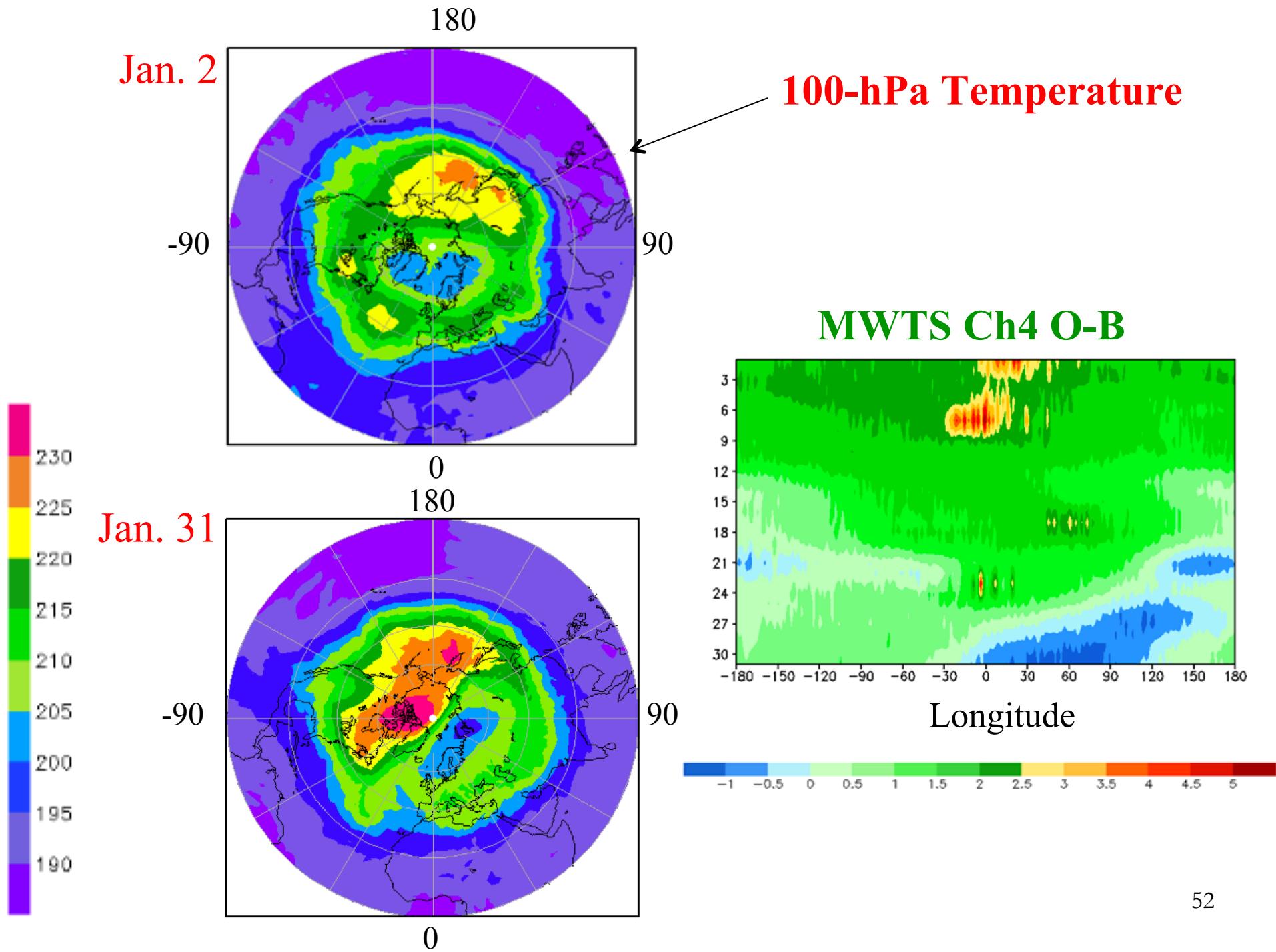
AMSU-A Ch9



Longitude

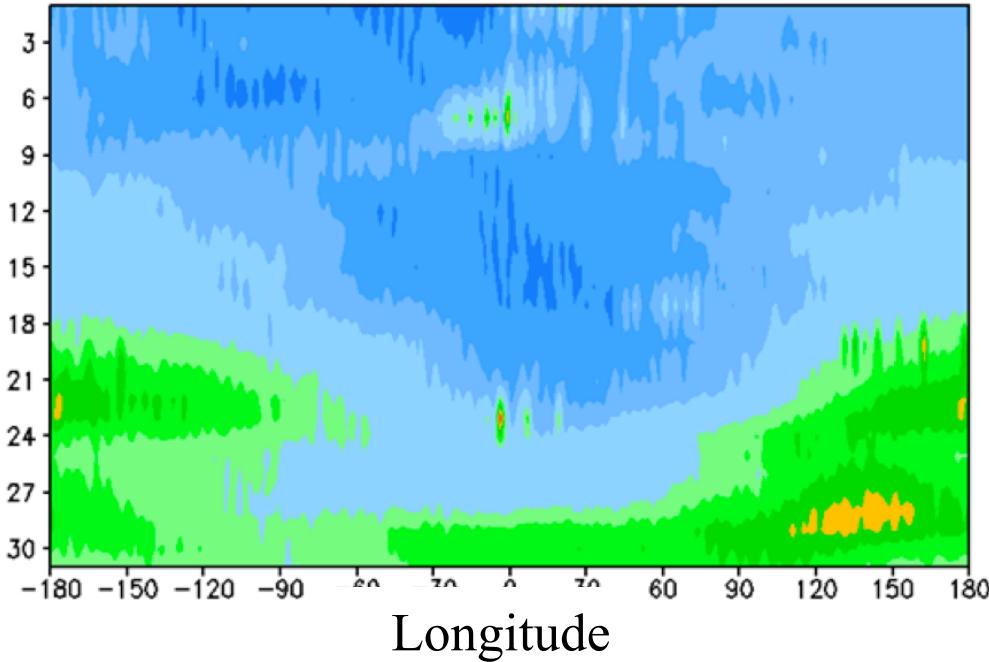
Longitude



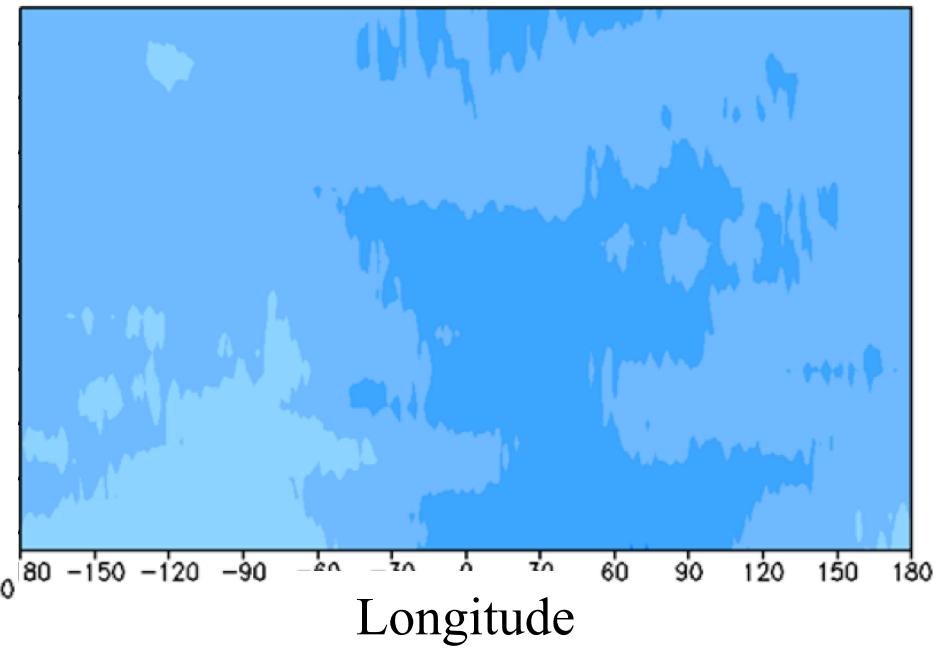


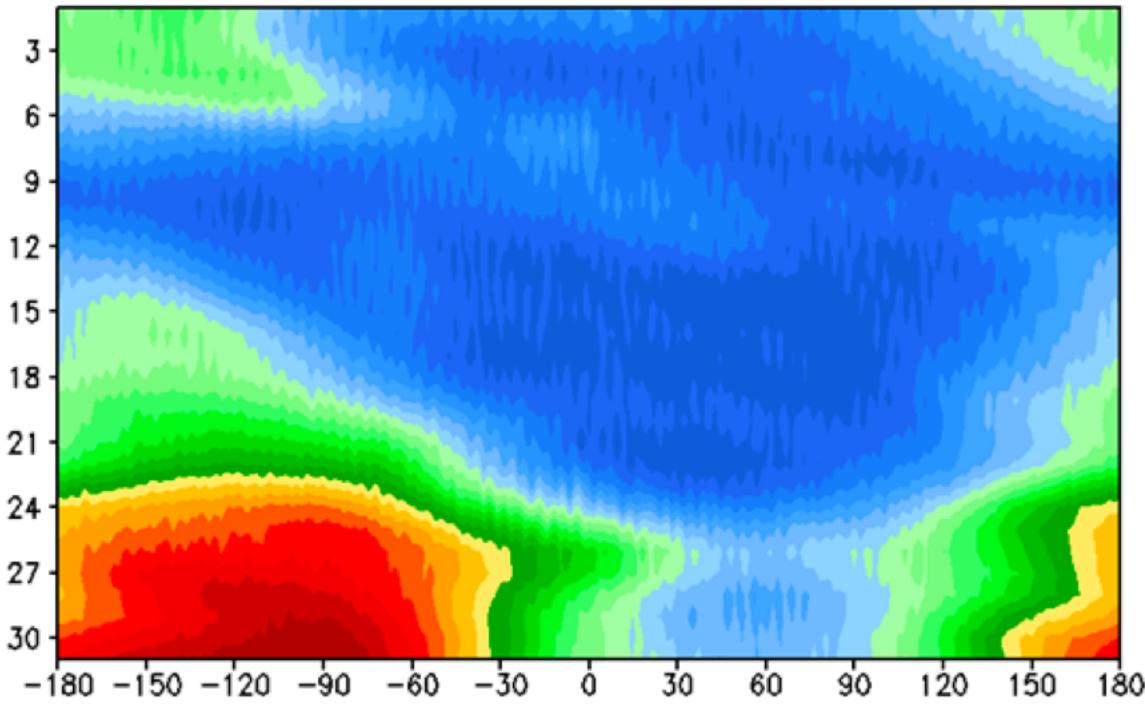
Weather-Dependence of MWTS Bias (O-B) in Northern Polar Region (78.5N-81.5N)

MWTS Ch3



AMSU-A Ch7

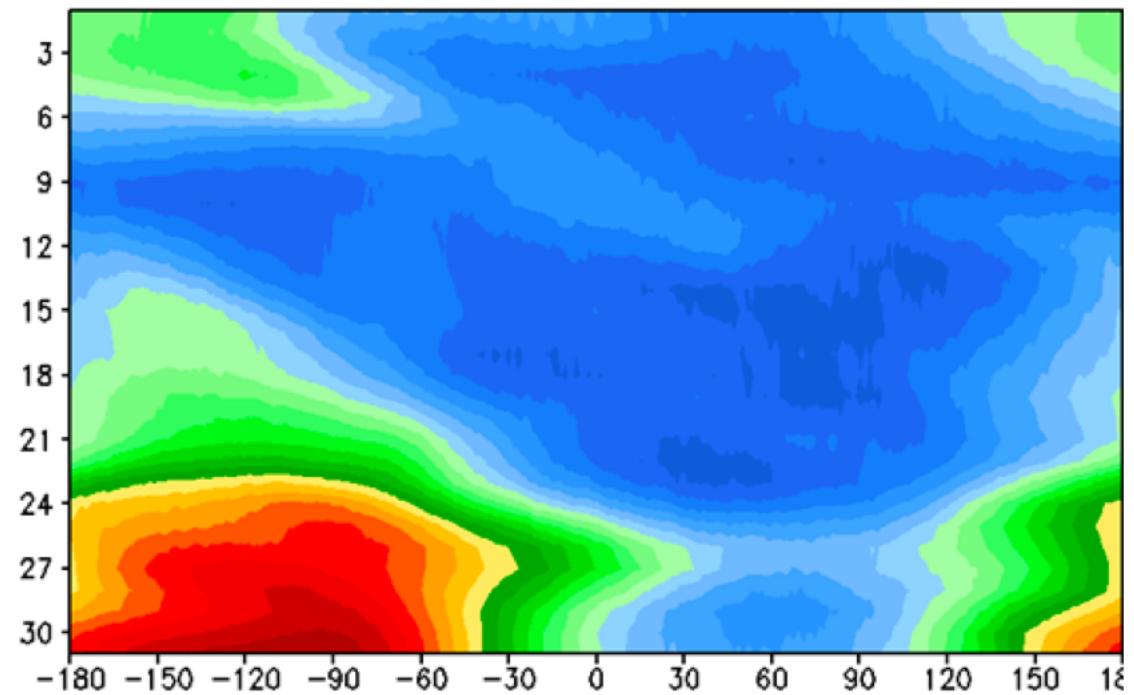


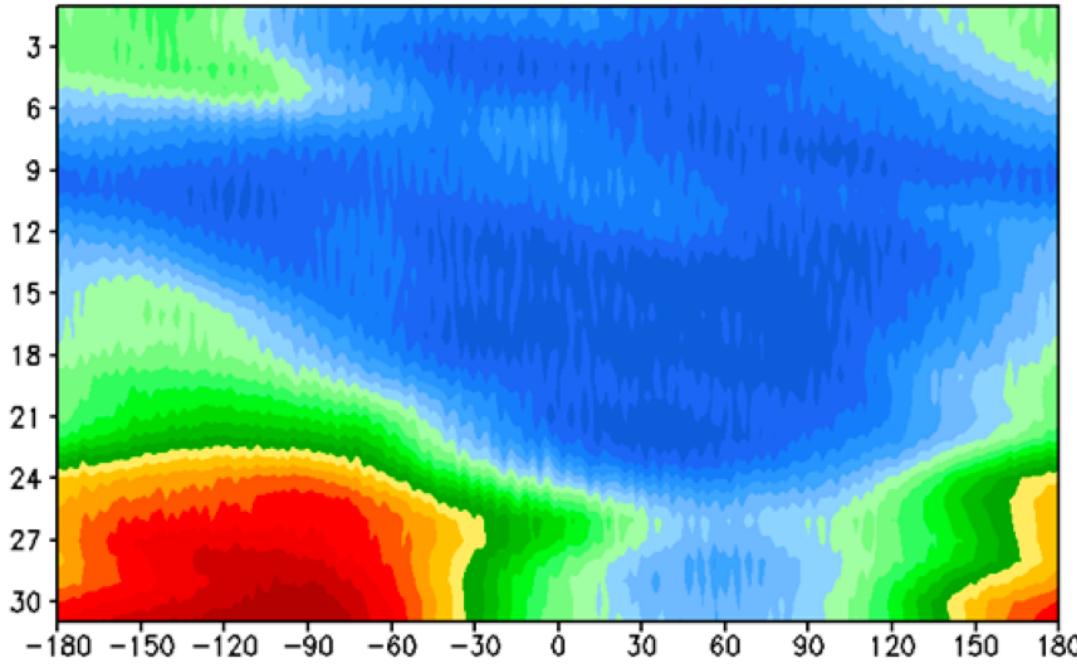


MWTS Ch3

AMSU-A Ch7

Observed T_b within
(78.5S-81.5S)

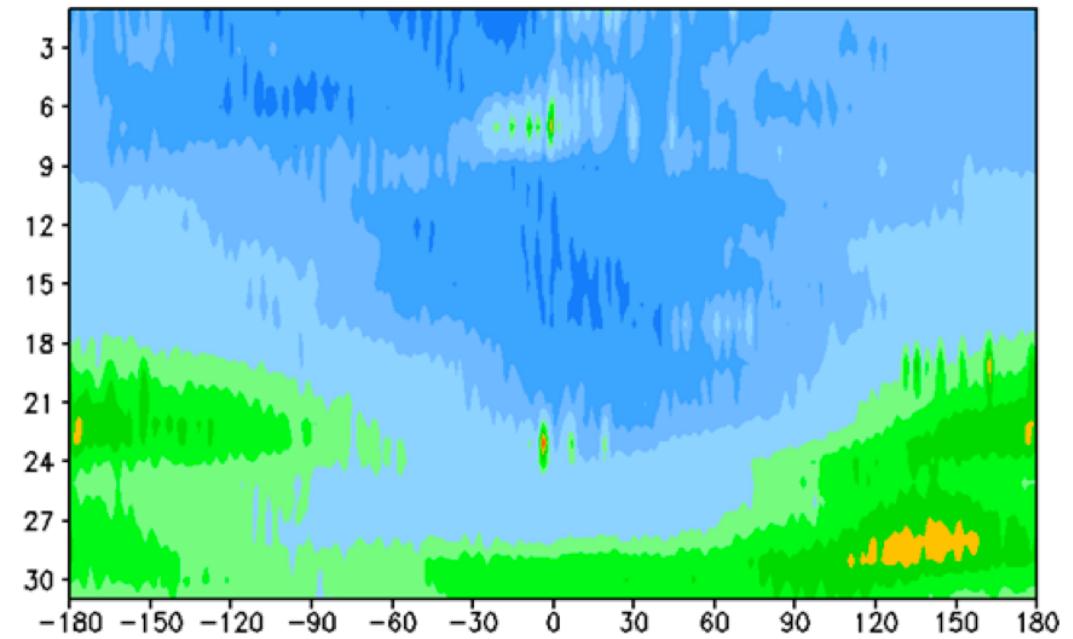




**Observed T_b within
(78.5N-81.5N)**

**Observations (O)
From MWTS Ch3**

O-B

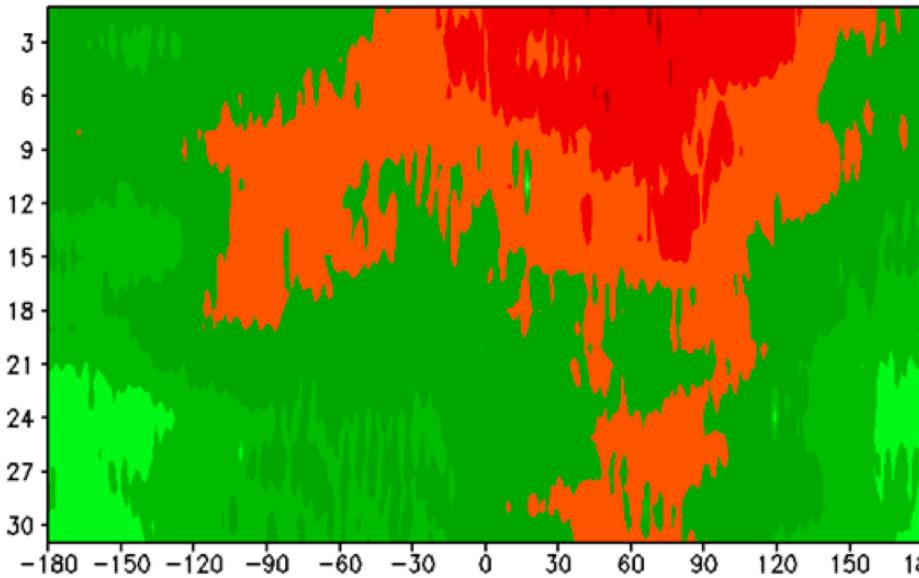


55



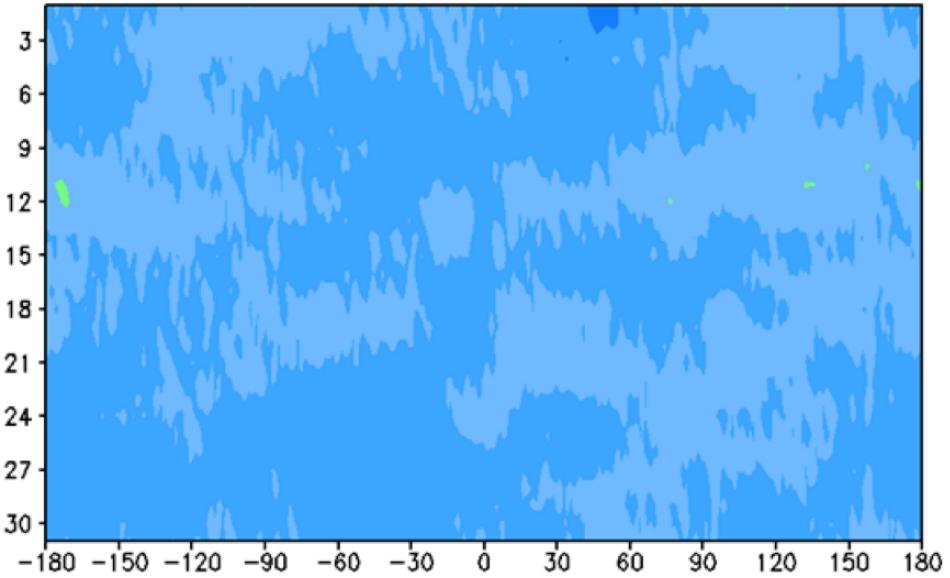
Weather-Dependence of MWTS Bias (O-B) in Southern Polar Region (78.5S-81.5S)

MWTS Ch3



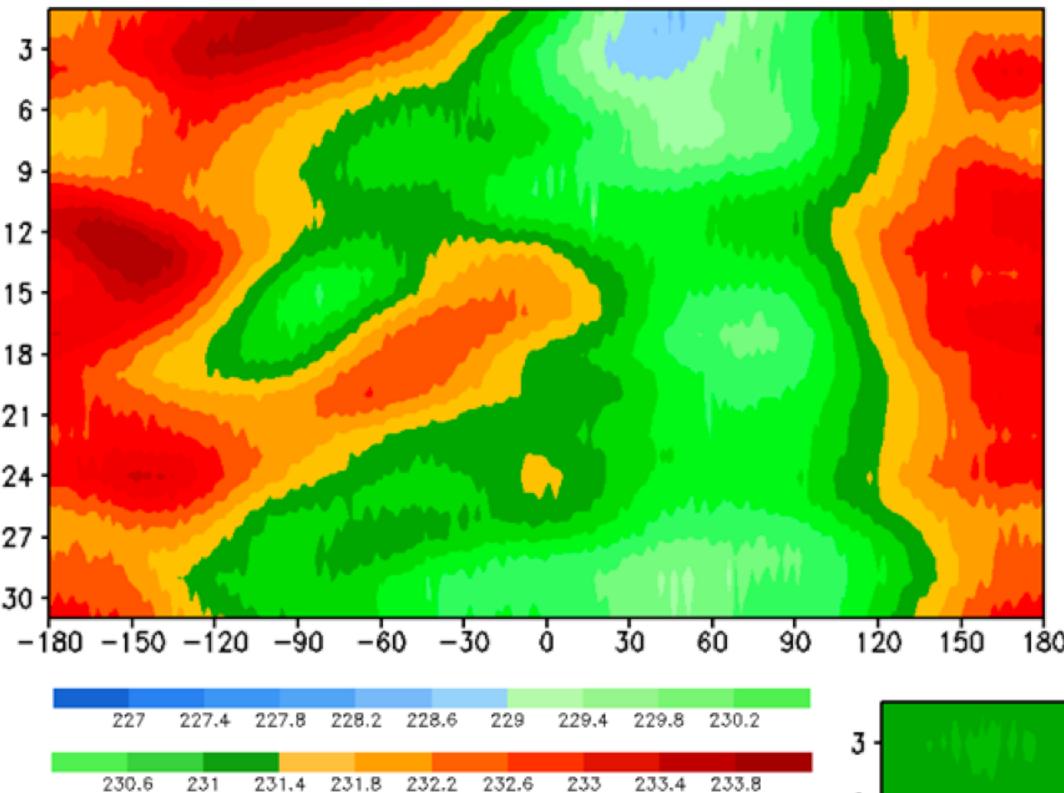
Longitude

AMSU-A Ch7



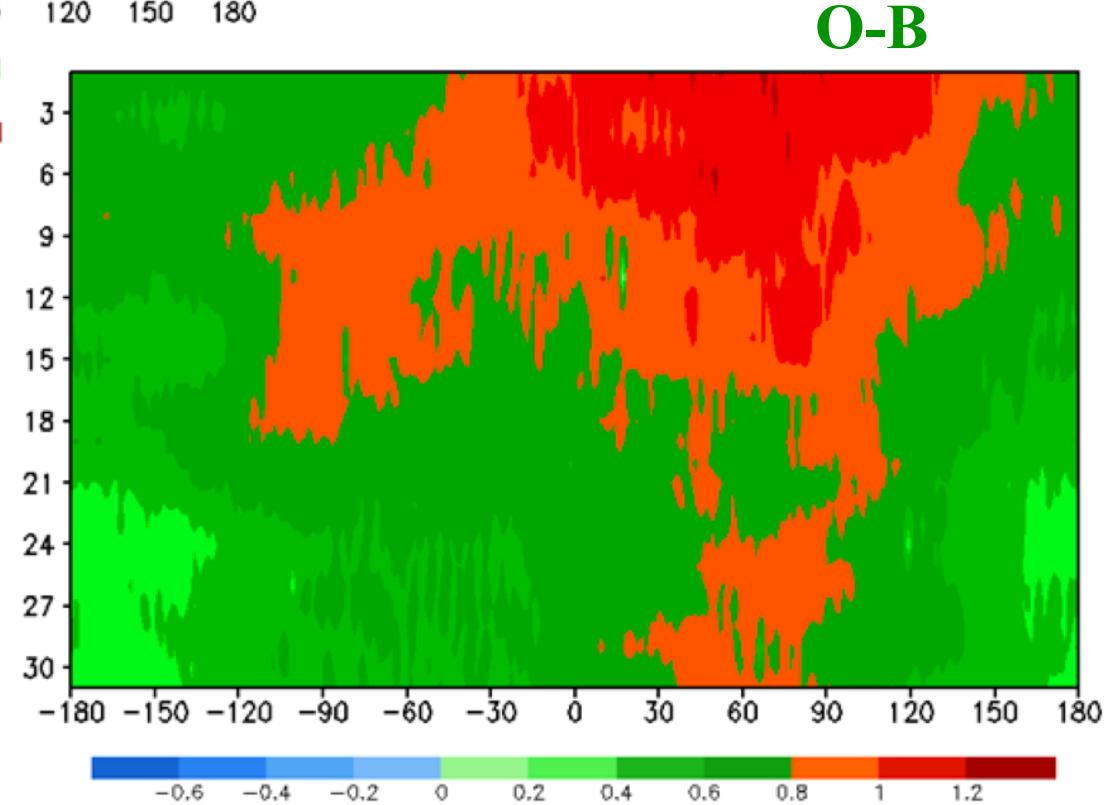
Longitude



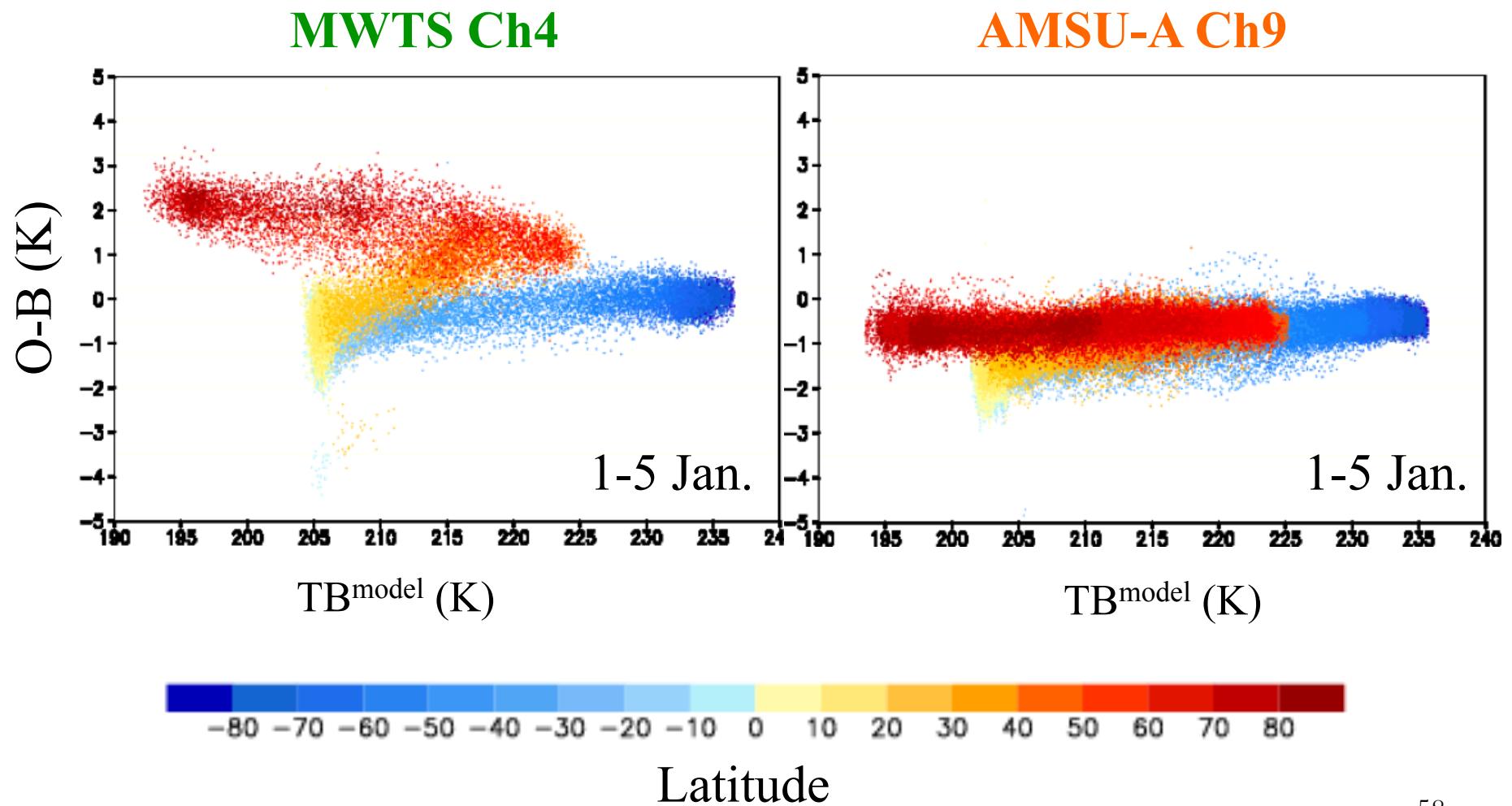


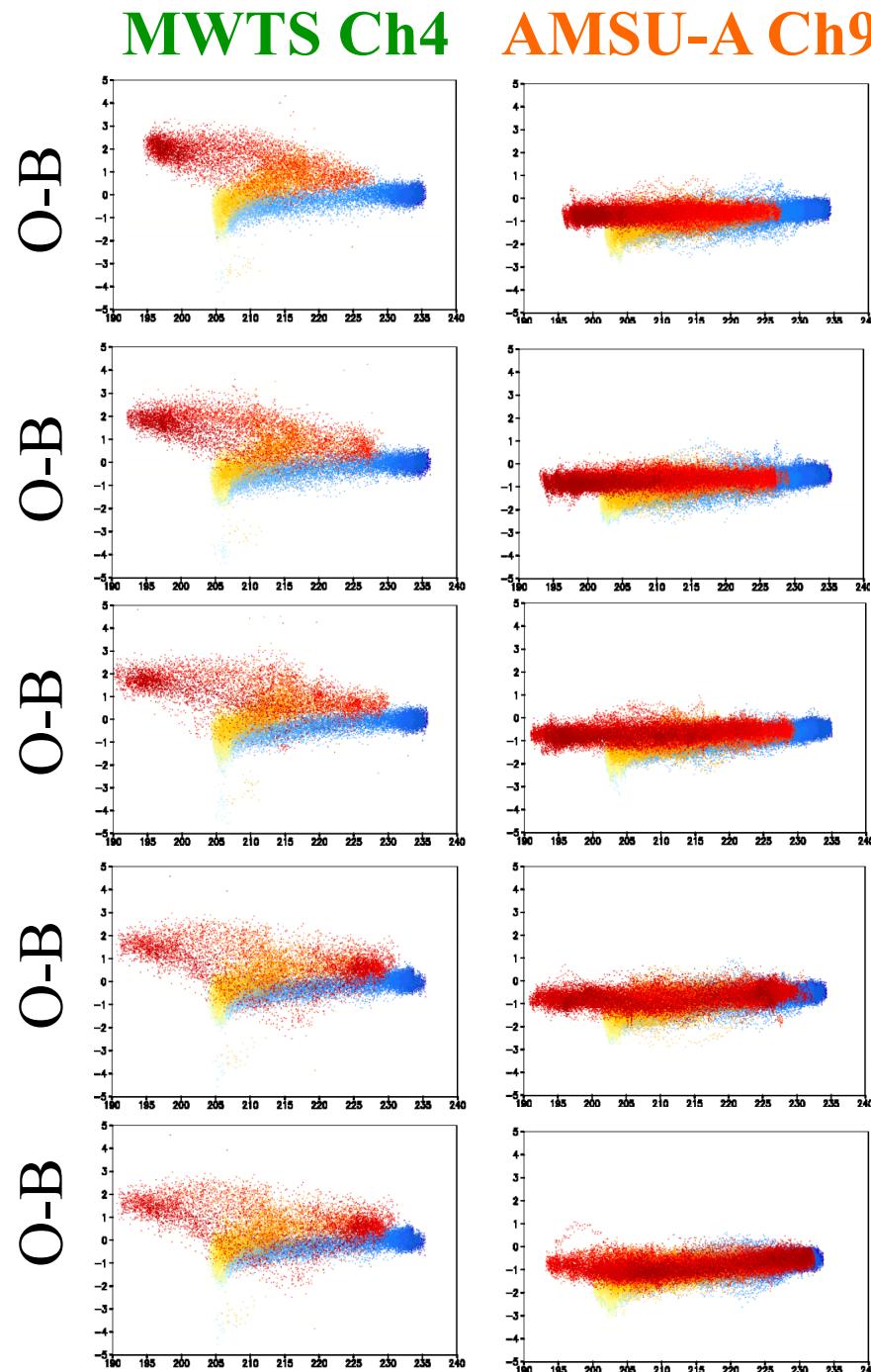
Observations (O)
From MWTS Ch3

Observed T_b within
(78.5S-81.5S)



Root-Cause Analysis of MWTS Global Biases





6-10 January 2010

11-15 January 2010

16-20 January 2010

21-25 January 2010

26-31 January 2010

Two-Point Calibration

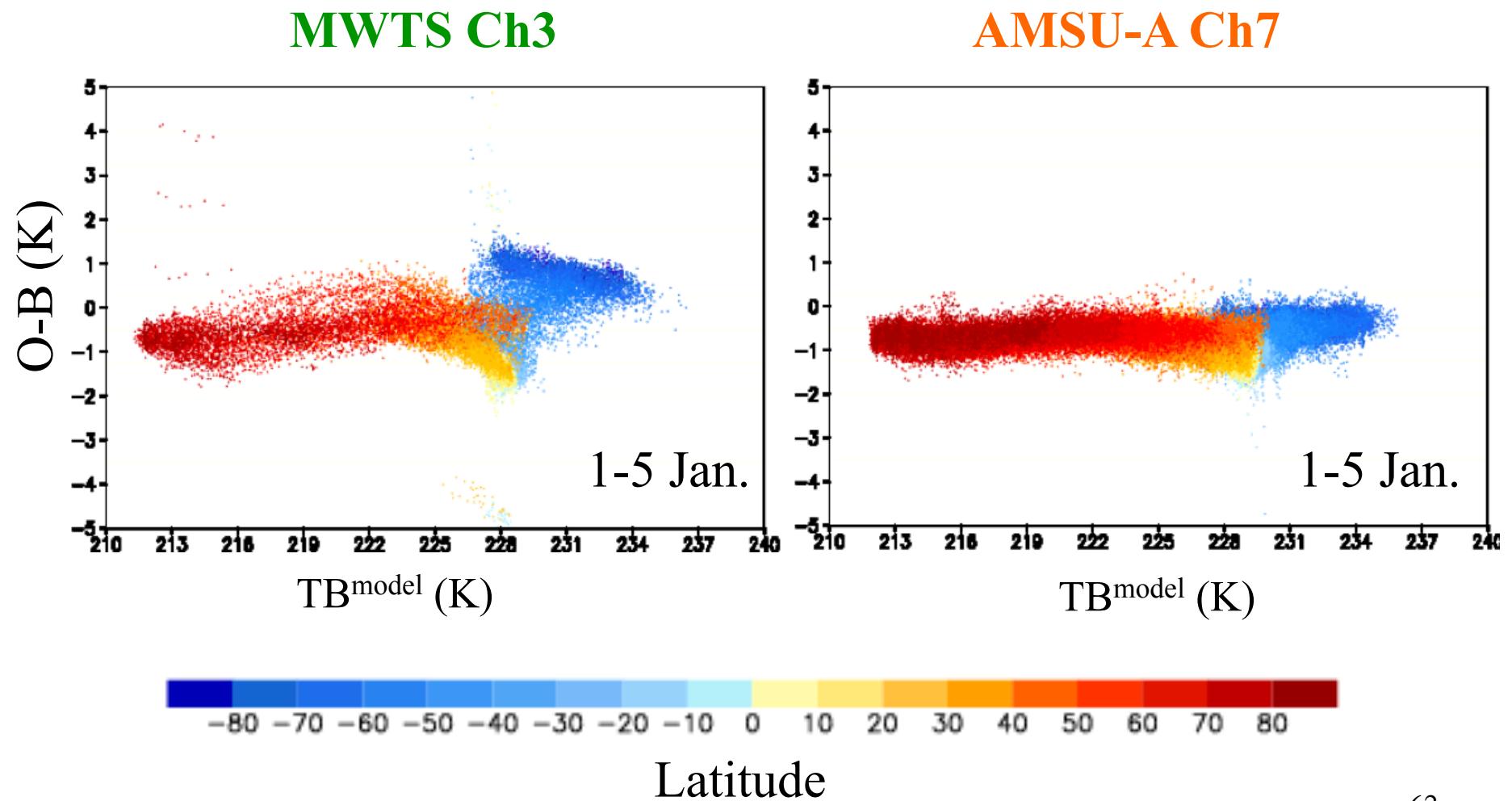
$$R_e = \underbrace{R_w + (R_w - R_c) \left(\frac{C_e - \bar{C}_w}{C_w - \bar{C}_c} \right)}_L + \underbrace{\mu (R_w - R_c)^2 \frac{(C_e - \bar{C}_w)(C_e - \bar{C}_c)}{(C_w - \bar{C}_c)^2}}_Q$$

$$\bar{C}_x(t_0) = \frac{1}{n+1} \sum_{i=-n}^n \left(1 - \frac{|i|}{n+1} \right) C_x(t_i)$$

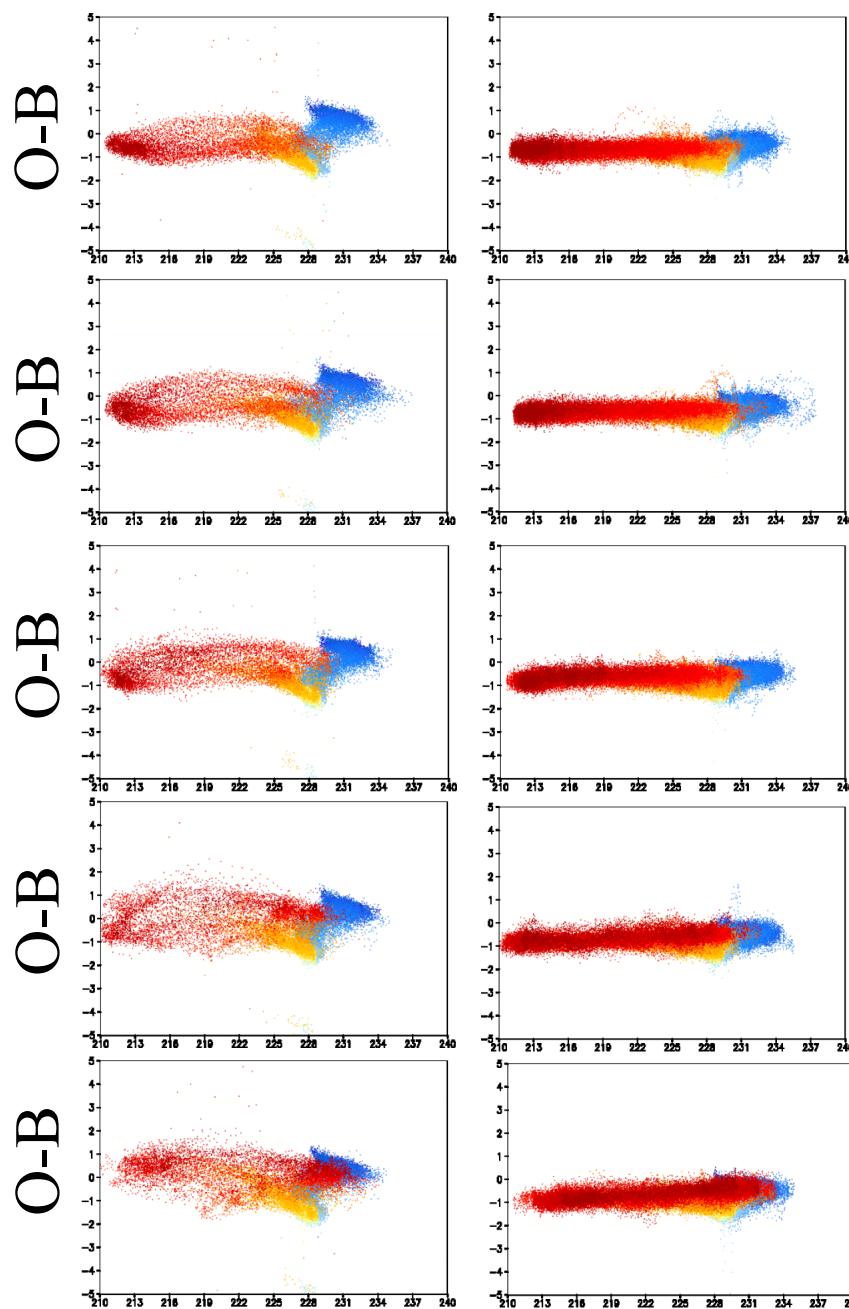
Scene-Temperature Dependence of Bias Could Be Caused by

- Nonlinearity
- Frequency Shift
- Antenna Emission
- Solar contamination

Root-Cause Analysis of MWTS Global Biases



MWTS Ch3 AMSU-A Ch7



6-10 January 2010

11-15 January 2010

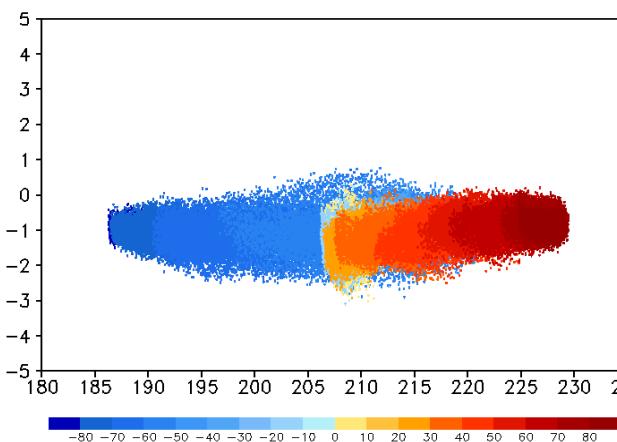
16-20 January 2010

21-25 January 2010

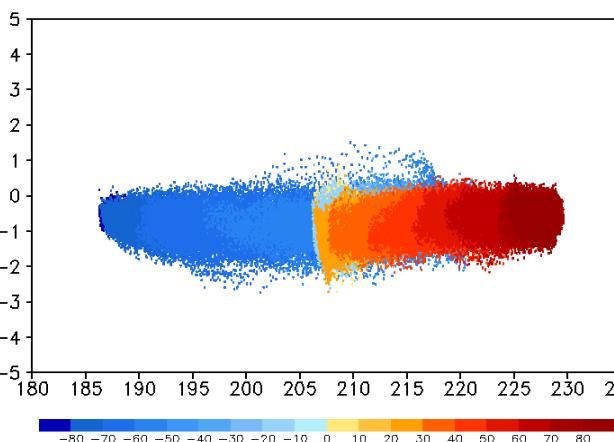
26-31 January 2010

Summer Case

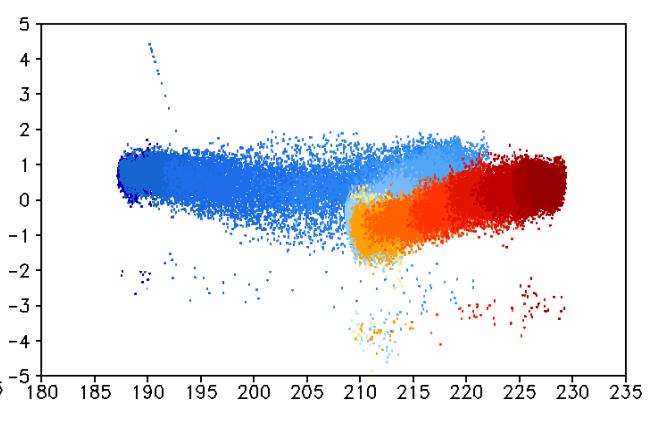
NOAA-18
AMSU-A Ch9



MetOp-A
AMSU-A Ch9



FY-3A
MWTS Ch4



August 29, 2010

Part II

Summary and Conclusions

1. Data bias of FY-3A MWHS is very similar to NOAA-18 MHS in terms of magnitude and characteristics.
2. Positive biases in channel 3 may be related to a wet bias in NCEP GFS FNL analyses.
3. Negative biases of channels 4 and 5 over land may be caused by both too large emissivity in RTM and too smooth model terrain.

Part III

Summary and Conclusions

- A latitudinal dependence of scan bias is found for both MWTS and AMSU-A data
- A scene-temperature dependence of bias is found for MWTS data near polar regions
- A significant nonlinearity is found for MWTS channels 3 and 4 global biases but not for AMSU-A channels 7 and 9
- A significant nonlinearity is found for both MWTS channel 2 and AMSU-A channel 5 global biases

More details can be found in:

Guan L., X. Zou, F. Weng and G. Li, 2010: Assessments of FY-3A Microwave Humidity Sounder ([MWHS](#)) measurements using NOAA-18 Microwave Humidity Sounder (MHS). *J. Geophy. Res.* (accepted)

Zou, X., X. Wang, F. Weng and G. Li, 2011: Assessments of Chinese FengYun Microwave Temperature Sounder ([MWTS](#)) measurements for weather and climate applications. *J. Ocean Atmos. Tech.*, (revised)

Lu, Q., W. Bell, P. Bauer, N. Bormann and C. Peubey, 2010: An initial evaluation of FY-3A satellite data. *ECMWF Technical Memoranda Number 631*, ECMWF, Shinfield Park, Reading, UK, ECMW. pp58.

Future Work

- Comparison between CRTM and RTTOV10 for FY-3 MWHS, MWTS and MWRI
- Link FY-3 data to NOAA and MetOp for establishing climate data record (CDR)
- Assimilation of FY-3 data in GFS WRF and Chinese GRAPES data analysis systems

Acknowledgment

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project 2010CB951600
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